OPERRA Deliverable D4.5

Analysis of stakeholder questionnaire responses

Description: This report will identify national and international stakeholders, collect stakeholder opinion, analyze feedback on research priorities and develop a stakeholder management strategy. This report is related to Task 4.3.

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Approval	**WP4 leader Sisko Salomaa: 6 July 2015**

PRIORITIES FOR RADIATION PROTECTION RESEARCH: ANALYSIS OF THE OPERRA STAKEHOLDER SURVEY

Report prepared for the OPERRA Management Board

A preliminary version of this report was presented at the 6th International MELODI workshop, organised 7-9 October 2014 in Barcelona, Spain. Since then, the preliminary report has been extended with further analysis of the open questions related to the SRA's and other minor revisions; nevertheless, the actual results of the e-survey remain unchanged.

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SUMMARY

This report provides an analysis of responses to the OPERRA eSurvey of stakeholder views on research topics of greatest relevance to radiation protection in Europe. The survey was carried out by members of the OPERRA project with assistance from members of the European radiation protection platforms, MELODI, EURADOS, NERIS and ALLIANCE, representing low dose risk, dosimetry, emergency planning and radioecology interests respectively. The response was encouraging, with 274 completed surveys for analysis from a range of types of respondent, mainly from those with a scientific background and considerable experience in the area. Most response came from those with interests in low dose risk and dosimetry, with least from those in the emergency planning and ethics areas. There were additionally NGO and a few public respondents. Responses were provided by 21 European countries plus some form countries further afield such as the USA, China, Russia and Egypt.

The eSurvey used the ZEF online evaluation tool and most questions asked for response in terms of perceived importance and feasibility of individual topics. The importance/feasibility ranking was used for gathering opinion on the 'synergistic' research topics, i.e. those considered to be of relevance to two or more of the four European platforms. A selection of such synergistic topics was recommended as the focus of the second OPERRA call for research proposals by the OPERRA Management Board.

Regarding the synergistic priorities the range and standard deviations on both importance and feasibility did not allow a very clear prioritisation. All topics received ratings of >60% importance and >49% feasibility, suggesting that research on all topics would be beneficial for improving radiation protection and could be feasible. While this level of endorsement by respondents is useful it does not assist in prioritisation. In the future more discriminating measures and metrics will have to be found to assist with prioritisation. In a post-survey open meeting held during the 2014 MELODI workshop this lack of prioritisation was noted but the survey was judged to be successful in initiating a consultation process and stimulating debate across a wide range of stakeholders. Similar difficulty in prioritisation of the MELODI, EURADOS, NERIS and ALLIANCE specific topics in the corresponding focus areas were encountered in using the importance/feasibility metrics.

This report includes a summary of lessons learned to help assist the improvement of future similar survey activities that inform research priorities and topics in Europe. Despite the limitations, the eSurvey results were clearly influential in that the higher ranked topics were successfully acted upon and reflected in the second OPERRA call, indicating the importance and influence of the eSurvey. This first eSurvey of stakeholder views on radiation protection research in Europe has therefore been successful and it is hoped that the experience gained in running this survey can be built upon in the future.

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1 INTRODUCTION

The EC funded Open Project for the European Radiation Research Area (OPERRA) aims to lead the establishment of long-term European research programmes in radiation protection. This will be achieved through the formation of an umbrella coordination structure that is legally empowered to administer future calls for research in all aspects of radiation protection.

Stakeholders' views on priority topics were collected through an eSurvey. This will help to stimulate an active dialogue with all parties having a significant interest in radiation protection.

The Strategic Research Agendas (SRAs) of the key platforms MELODI (Multidisciplinary European Low Dose Initiative), ALLIANCE (the European Radioecology ALLIANCE), NERIS (Preparedness for Nuclear and Radiological Emergency Response and Recovery) and EURADOS (the European Radiation Dosimetry Group), collaborated with OPERRA WP 4.3.2 to develop the content of the eSurvey. In addition, the key platforms helped with distribution of the questionnaire to the various research communities and other stakeholders as well as with motivation to respond.

This report presents the responses and views expressed by stakeholders related to priorities for radiation protection research collected by eSurvey.

2 METHODOLOGY

2.1 DATA COLLECTION

The request to respond to the eSurvey was distributed by email to the various contact lists of the four platforms (MELODI, ALLIANCE, EURADOS and NERIS). In addition, stakeholders involved in other relevant EC projects (e.g. EAGLE) and members of informed civil society listed below were asked to distribute the link to the eSurvey among their members using their newsletters, etc. The platforms, associations, coordinators of FP7 projects and representatives of informed civil society were asked to distribute the link to the eSurvey to their members in order to ensure anonymity and membership data confidentiality. The link to the eSurvey was common to all responders. In addition to platforms and associations, the eSurvey was distributed to a number of European and other international organisations.

The collection of data was carried out between 1/07/2014 and 15/09/2014. Within this period, three reminders were sent out: a first reminder on 1st of August, a second reminder on 1st of September and a final reminder on 9th of September 2014. Data were collected using the eSurvey tool Z-scored Electronic Feedback (ZEF). The ZEF Evaluation Engine® collected data and opinions from groups and individuals that were contacted. Responding to each survey section took around 15-30 minutes, with a likely maximum of around two hours for entire eSurvey if all focus areas selected.

If a respondent wanted to interrupt completion of the survey and continue at a later time, it was possible by copying their personal link from the address bar of respondent's browser, and saving it. To return, the respondent needed to paste personal link back to the address bar again. We noticed, that few respondents (2) submitted their partial answer two-times (1 respondent) or three-times (1 respondent). Since it is not possible to identify anonymous respondents submitting their partial answers more than one time, we decided to analyse all submissions.

2.1.1 Platforms

The four platforms involved in the eSurvey development, were:

MELODI

ALLIANCE

NERIS

EURADOS

2.1.2 European organisations and projects

The European organisations and projects (14), asked to participate in the eSurvey, were:

CIRSE (Cardiovascular and Interventional Radiological Society of Europe)

EAN- European ALARA Network for Naturally Occurring Radioactive Materials

EANM (European Association of Nuclear Medicine)

EFOMP (European Federation of Organisations in Medical Physics)

EFRS (European Federation of Radiographer Societies)

EIBIR (European Institute for Biomedical Imaging Research)

ERRS (European Radiation Research Society)

ESCR (European Society of Cardiac Radiology)

ESER (European Society of Emergency Radiology)

ESR (European Society for Radiology)

ESTRO (European Society for Radiotherapy and Oncology)

ISOE - ETC (Information System on Occupational Exposure - European Technical Center)

HERCA (Heads of European Radiological protection Competent Authorities)

FP7 project EAGLE (Enhancing educAtion, traininG and communication processes for informed behaviors and decision-making reLatEd to ionising radiation risks)

2.1.3 Other international organisations

The international organisations (16), asked to participate in the eSurvey, were:

IAAR (International Association for Asset Recovery)

IAEA (International Atomic Energy Agency)

IARC (International Agency for Research on Cancer)

ICRP (International Commission on Radiological Protection)

ICRU (International Commission on Radiological Units)

IEC (International Electrotechnical Commission)

IOMP (International Organization for Medical Physics)

IRPA (International Radiation Protection Association)

ISO (International Organization for Standardization)

ISOE (Information System on Occupational Exposure)

OECD Nuclear Energy Agency (NEA)

NCRP (National Council on Radiation Protection & Measurements)

NEA/OECD (Nuclear Energy Agency/ Organisation for Economic Co-operation and Development)

UNEP (United Nations Environment Programme)

UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation)

WHO (World Health Organization)

2.2 FORMULATION OF E-SURVEY ITEMS

After consultation with the platforms, most items in the eSurvey were formulated as questions or statements, to which the respondent could select a quantitative answer point on a two-dimensional graph (x/y coordinates) by using ZEF tool. When evaluating the research topics, the typical selection for x/y-coordinates was the feasibility/importance value pairing, in which case the importance value is defined as increasing when moving up the table and the feasibility values defined as moving to the right. Consequently, important research topics are filtered into the upper right corner, while less important research topics are filtered into the upper left corner.

For some questions, the respondents were asked to answer using a five points Likert-scale. For instance, the level of agreement with certain statements was measured on a scale ranging from strongly disagree, through to disagree, undecided, agree, to strongly agree. The option “no answer” or “I don’t know” was allowed. The answer categories were adjusted to the context of the statement or question.

Free answer questions were used to allow respondents to specify other research topics for the domain or to provide further comment. The content of these free texts is reported and summarized in annex 1 (pp 94)

Multiple choice answers were included for selected research domains. For instance, in one platform focus area the respondents needed to select the three most important research lines in the domain to be addressed over the next 20 years.

2.2.1 Testing the eSurvey

Testing of the questionnaire was carried out by the OPERRA Management Board (MB), as a pre-test of the e-Survey with an electronic version of the questionnaire. Respondents were asked to test the questionnaire and to write comments, if appropriate. This provided an opportunity to identify any problems respondents might have, e.g. technical problems or questions that are too difficult to answer.

The testing of the eSurvey was performed between 23rd of June 2014 and 30th of June 2014. The comments were discussed by OPERRA WP4 group participants. Questionnaire was improved and final version written by STUK.

2.3 STRUCTURE OF THE E-SURVEY

The eSurvey began with a section coordinated among platforms concerning ‘synergistic priorities’ relevant to two or more of MELODI, ALLIANCE, NERIS and EURADOS. To start, all responders were requested to assess the importance and feasibility of such ‘synergistic priorities’.

Next, the respondent was asked to select one or more focus areas relevant to radiation protection: low dose risks, individual and general health and radiation protection, radioecology, preparedness for nuclear and radiological emergency response and recovery, and radiation dosimetry - each covering the research priorities identified in the SRAs of the four platforms mentioned above. Among the focus areas the eSurvey also contains questions concerning ethical aspects, risk communication and risk perception and education & training issues relating to radiation protection.

The background information of the responder was included at the very end of the questionnaire. The responders could leave their contact details for future communication but it was also possible to complete the eSurvey anonymously (for all questionnaire see annex 2: pp. 99).

For further details, the OPERRA eSurvey practical instructions were offered (see annex 3: pp. 125).

2.4 DATA ANALYSIS

For the data analysis three statistical packages were used: ZEF, EXCEL statistics and SPSS.

For the synergistic research topics, the analysis was also done individually for responses from each platform.

2.5 LESSONS LEARNED

As will become clear from reading the results and analyses in Chapter 3, the eSurvey has been valuable in helping to inform the research topics prioritised by OPERRA, particularly in its second call. This is encouraging especially as this is the first eSurvey run to help gather stakeholder feedback on the research priorities for European Radiation Research. Nonetheless there were several insights gained by those involved in the activity and these ‘lesson learned’ are summarised below. These are provided to help those who may be considering similar activities in the future.

- The ZEF feasibility/importance scale did not provide good deiscrimination between different options; therefore, a simpler and more discriminating way to rank priorities would be beneficial (eg, top 3 or 5 ranked priorities).
- The survey was too complex to encourage a majority of completions (completion rate ~ 50%); a simpler, shorter format should help drive up response and completion rates.
- Analysis output from ZEF was not as readily usable as expected.

- An effective way to encourage a greater number of responses from outside the MELODI/MENA community is needed; again simpler format could help and possibly a greater emphasis on targeting those from whom response would be valued.

- Alternative survey tools as used by SCK or available through Google may be of use. STUK has the license for Webropol tool; a variety of options should be examined and evaluated

3 RESULTS

3.1 RESPONDENTS

3.1.1 Response to the eSurvey

The eSurvey was opened 507 times. 233 times the e-Survey was not submitted and 274 it was submitted. Only these 274 submissions were taken as valid responses and analysed. Each submission was considered separately in the analysis, although we noticed incidentally (based on the email provided) that three respondents appeared to have submitted the eSurvey more than once (twice and three-times). For more information see section Data collection.

3.1.2 Platforms, associations and other stakeholders participating in the eSurvey

As expected, members of the MELODI platform were the most frequent responders to the eSurvey, followed by EURADOS members. Stakeholder engagement in the eSurvey was quite successful since we received more than forty submissions from other relevant EC projects and more than fifty submissions from other stakeholders, mainly members of informed civil society.

Submissions of eSurvey per platforms, associations and other stakeholders:

120 from MELODI,
119 from EURADOS,
78 from ALLIANCE,
70 from NERIS
43 submissions from other relevant EC projects and
55 submissions from stakeholders neither indicating platforms nor EC projects.

In 86 submissions it was indicated that the respondent belonged to more than one platform or association;

EURADOS & MELODI	78
ALLIANCE & MELODI	58
EURADOS & NERIS	52
ALLIANCE & NERIS	44
EURADOS & NERIS & ALLIANCE	38

Stakeholders from European FP7 projects were broadly engaged in the eSurvey. We received 43 submissions from active participants in the following projects or organisations:

ARCADIA, EAGLE, COMET, STAR, ENETRAP III, PiDRL, EUTEMPE-RX, EUTERP, EPI CT – CURE, ESARDA, EURAMET, EuroFusionConsortium project, Geronimo, MEDRAPET, EMAN. EUTEMPE-RX., MEDRAPET, EMAN, HERCA (through EANM), MetroNORM, MODARIA, NORM4BUILDING, OPERRA, DoreMi, SOLO, RENEB, PREPARE, NERIS-TP, EURADOS WG7, PROTECT, RENEB, BIOQUART, WP-MED Article 31, IAEA, ICRP and IOMP.

3.1.3 Submissions of eSurveys in an institutional name

Thirteen out of 274 responses were submitted in an institutional capacity. The institutional opinion was submitted by:

- CEA–France
- CIEMAT
- CIEMAT Knowledge management and E&T Division
- Department of Radiation Oncology, Medical Faculty C.G.C., Technische Universität, Dresden
- EFOMP
- EFOMP on behalf of EIBIR
- Hellenic Centre for Marine Research
- ICRU
- National Radiation Protection Institute, Prague
- NCSR"D"/INRASTES/ERL
- OncoRay Dresden
- PHE–CRCE
- Southern Urals Biophysics Institute

3.1.4 Respondent's experience in the field

Respondents to the eSurvey were generally well experienced. Most had been interested in or worked in radiation protection (including education) for many years.

- 22 respondents have less than 5 years of experience
- 86 respondents have 6-15 years of experience
- 70 respondents have 16-25 years of experience
- 50 respondents have 26-35 years of experience
- 41 respondents have more than 35 years of experience.

The main involvement of respondents in the field of radiation protection is the following:

- Research: 212
- Controlling and advisory activities: 25
- Regulator's work: 52
- Working in the nuclear industry: 10
- Radiation workers in the health care sector: 9
- Members of the public with an interest in the radiation protection field: 3

The respondents worked for a range of different types of institutions (multiple selections possible):

- 216 work for scientific institutions (e.g. university, research institute…)
- 24 work for regulatory bodies
- 14 work for controlling authorities
- 22 are users of ionising radiation (e.g. hospital, operator of nuclear installation…)
- 7 work for the industry
- 11 are consultants
- 12 are employees of international organisations
- 3 work for NGO's
- 12 work for other institutions.

3.1.5 Geographical distribution of views and opinions collected with the eSurvey

Twenty one European Union countries participated in the eSurvey. In addition, we received submissions from Norway and Switzerland. International institutions such as IAEA or ICRU also shared their opinions. Geographical distribution of views and opinions related to radiation protection research and collected by eSurvey was broad and went well beyond Europe's borders. Responses were also received from non-European countries, for instance India, Egypt, Canada, China and United States.

EU responders were not asked to specify their country. Thus, for more than a hundred submitted eSurveys it was not possible to identify from which country they were submitted. In total, there were 229 submissions from EU member states, 14 submissions from other European countries, 23 submissions from non-European countries and 8 responders didn't answer to this question.

Although EU responders were not asked to indicate their country, for those who provided personal information it was possible to elicit the geographical background, as follows (European Union countries are highlighted in bold):

Austria	**3**
Belgium	**9**
Bulgaria	**1**
Canada	3
China	1
Croatia	**2**
Czech Republic	**3**
Egypt	1
Finland	**5**
France	**26**
Germany	**14**
Greece	**3**
Hong Kong	1
Hungary	**2**
India	1
Ireland	**1**
Italy	**16**
Netherlands	**6**
Norway	1
Poland	**4**
Portugal	**5**
Romania	**4**
Russia	4
Serbia	3
Slovenia	**2**
Spain	**11**
Sweden	**4**
Switzerland	3
Turkey	1
Ukraine	2
United Kingdom	**13**
United States	6
Other international organisations	8

Not mentioned	105
Sum	274

3.2 SYNERGIES BETWEEN RESEARCH AREAS

European research efforts in radiation protection need to be coordinated to help ensure effective and efficient use of the limited funds available. The respondents were asked to share their opinion on the importance and feasibility of fifteen topics that have been identified as relevant to more than one of the research areas covered by the European research platforms MELODI, NERIS, EURADOS and ALLIANCE. These concern low dose risk, emergency and recovery preparedness, radiation dosimetry and radioecology respectively. The 'synergistic priorities' have been developed through consultative process among the platforms as part of the OPERRA project.

The OPERRA MB decided to focus the 2nd OPERRA call on synergistic topics, to stimulate/initiate the collaboration among the researchers of MELODI, ALLIANCE, NERIS and EURADOS, who signed a Memorandum of Understanding on 5/12/2013, to collaborate on radiation protection research.

3.2.1 Overall support for the synergistic research topics

Table 1 shows the general support for the synergistic priorities nominated by the different platforms, in terms of the mean score that each research topic received from the respondents (1 low, 100 high), standard deviation of responses and number of submitted responses. More than 240 opinions were submitted assessing the feasibility and the importance of the proposed research topics. Almost all research topics received an average score higher than 50 scores related to both feasibility and importance. Although, the scores for these research topics are very similar, the largest difference in opinion was observed for the importance of the topic "Inter- and intra-species differences in radiosensitivity" (std. = 23), identified by MELODI and ALLIANCE.

Table 1: General support for synergistic research topics

Research topic/identified by		MEAN (1-100)	Standard deviation	N of submissions
Identified by MELODI, ALLIANCE and EURADOS Multiple stressors and modulation of radiation effects in living organisms	Feasibility	49	22	
Multiple stressors and modulation of radiation effects in living organisms	Importance	68	19	235
Identified by ALLIANCE, NERIS and EURADOS Spatial and temporal environmental modelling and human dose assessment after a nuclear accident.	Feasibility	65	21	
Spatial and temporal environmental modelling and human dose assessment after a nuclear accident.	Importance	72	20	250
Priorities for pre-accident recovery preparedness.	Feasibility	66	19	
Priorities for pre-accident recovery preparedness.	Importance	67	22	247
Decision support based on multi-criteria decision aiding tools in the various phases of an emergency (including the post-emergency remediation phase).	Feasibility	60	19	
Decision support based on multi-criteria	Importance	66	21	252

decision aiding tools in the various phases of an emergency (including the post-emergency remediation phase).				
Identified by NERIS, MELODI and EURADOS Development of health surveillance procedures	Feasibility	67	20	
Development of health surveillance procedures	Importance	72	20	249
Biological indicators of radiation exposure, effects, health risk and disease susceptibility to inform emergency management and epidemiological studies.	Feasibility	58	21	
Biological indicators of radiation exposure, effects, health risk and disease susceptibility to inform emergency management and epidemiological studies.	Importance	74	19	255
Identified by NERIS and EURADOS Development of monitoring strategies_ processes and tools.)	Feasibility	68	20	
Development of monitoring strategies_ processes and tools.	Importance	74	19	253
Identified by MELODI and EURADOS Improvement in the modelling of biokinetics and dosimetry of internal emitters.	Feasibility	60	19	
Improvement in the modelling of biokinetics and dosimetry of internal emitters.	Importance	68	21	246
Improved organ dosimetry in epidemiological studies.	Feasibility	60	21	
Improved organ dosimetry in epidemiological studies.)	Importance	67	21	248
Update personalized dosimetry in medical applications.	Feasibility	67	21	
Update personalized dosimetry in medical applications.	Importance	68	23	245
Investigation of the biological effectiveness of different radiation qualities and prediction of biological risks.	Feasibility	59	22	
Investigation of the biological effectiveness of different radiation qualities and prediction of biological risks.	Importance	69	22	245
Identified by MELODI and ALLIANCE The roles of genetic and epigenetic changes in heritable/transgenerational and somatic effects relevant to individual and population health.	Feasibility	52	22	
The roles of genetic and epigenetic changes in heritable/transgenerational and somatic effects relevant to individual and population health.	Importance	69	20	250
Inter- and intra-species differences in radiosensitivity.	Feasibility	50	22	
Inter- and intra-species differences in radiosensitivity.	Importance	65	23	250
Biomarkers of exposure and effects in living	Feasibility	55	22	

organisms.				
Biomarkers of exposure and effects in living organisms.	Importance	71	21	250
Identified by ALLIANCE and NERIS	Feasibility	62	20	
Urban radioecological hydrology modelling in (post)-emergency conditions.				
Urban radioecological hydrology modelling in (post)-emergency conditions.	Importance	61	22	248

Figure 1 shows that the feasibility and importance of the fifteen research topics selected slightly differed. Feasibility scores varied more among the topics than importance scores, ranging from 49 to 68 and from 61 to 74 respectively. In general, the topics “Development of monitoring strategies, processes and tools” and “Biological indicators of radiation exposure, effects, health risk and disease susceptibility to inform emergency management and epidemiological studies” were recognised as the most important. The research topic “Development of monitoring strategies, processes and tools” was recognised as the most feasible. The topic related to “Multiple stressors and modulation of radiation effects in living organisms” was identified as the least feasible, whereas the “Urban radioecological hydrology modelling in (post)-emergency conditions” was considered the least important topic. It is noteworthy to remark that the difference among the scores is modest.

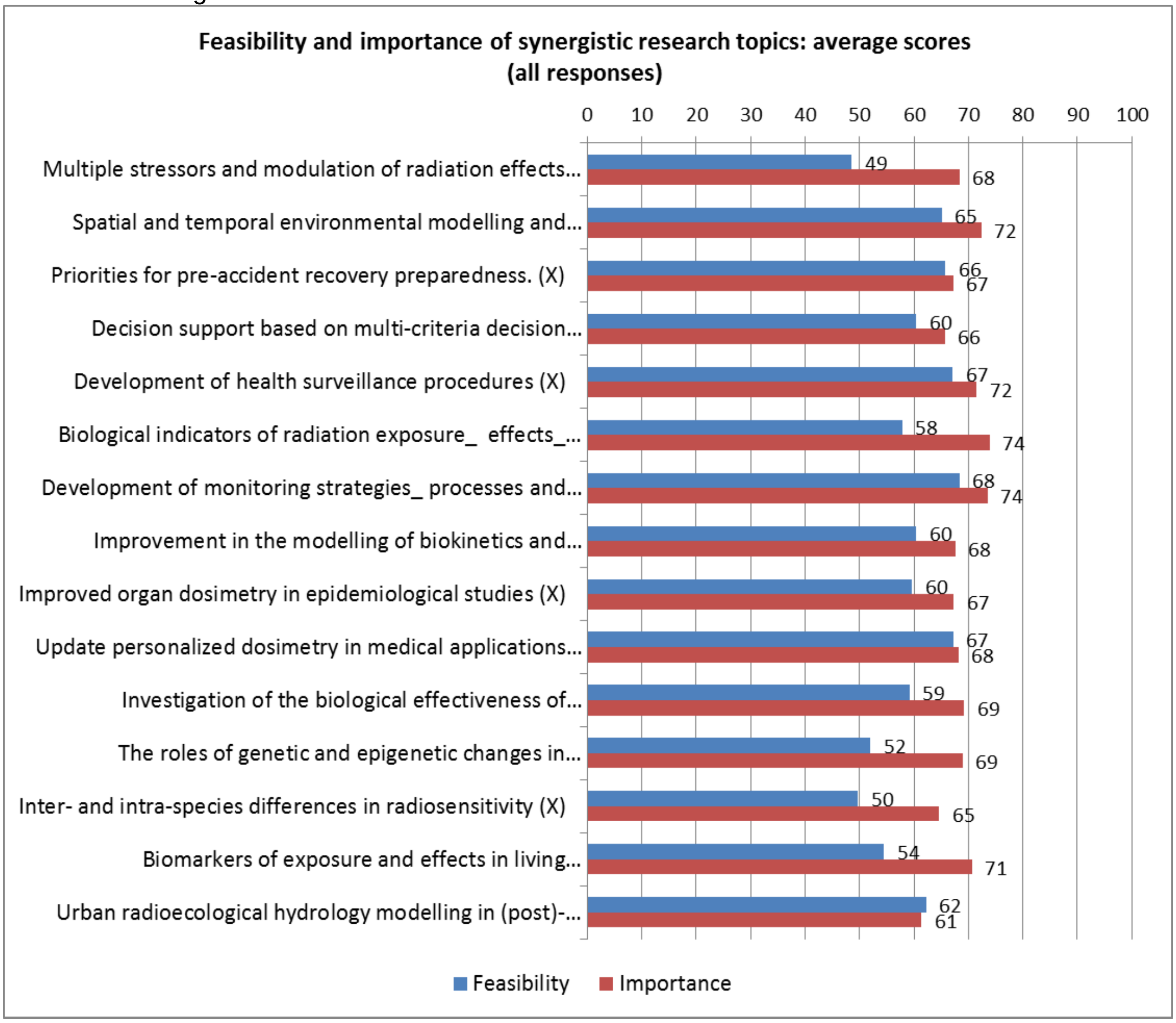


Figure 1: Mean score of feasibility and importance of synergistic research topics. The number of respondents is between 235 and 255

Table 2 and Figure 2 show the opinion of the members of different platforms concerning the importance of the selected research topics. It can be noticed that NERIS, EURADOS, ALLIANCE and MELODI have generally similar opinions of the importance of the selected research topics: these differ by 10% at most. As 86 respondents stated that they belong to more than one platform, the general level of agreement is not surprising.

Table 2: Average importance score of synergistic topics per platform

Importance of research topic/number of submitted eSurveys per platform (score 1-100)	NERIS	EURADOS	ALLIANCE	MELODI
Multiple stressors and modulation of radiation effects in living organisms.	69	68	72	70
Spatial and temporal environmental modelling and human dose assessment after a nuclear accident.	80	76	78	71
Priorities for pre-accident recovery preparedness.	73	66	72	65
Decision support based on multi-criteria decision aiding tools in the various phases of an emergency (including the post-emergency remediation phase).	70	66	67	64
Development of health surveillance procedures.	78	72	73	73
Biological indicators of radiation exposure, effects, health risk and disease susceptibility to inform emergency management and epidemiological studies.	71	76	73	75
Development of monitoring strategies, processes and tools.	78	75	76	73
Improvement in the modelling of biokinetics and dosimetry of internal emitters.	69	70	68	68
Improved organ dosimetry in epidemiological studies.	70	72	67	70
Update personalized dosimetry in medical applications.	67	74	68	68
Investigation of the biological effectiveness of different radiation qualities and prediction of biological risks.	66	72	72	70
The roles of genetic and epigenetic changes in heritable/transgenerational and somatic effects relevant to individual and population health.	66	68	68	71
Inter- and intra-species differences in radiosensitivity.	62	64	68	67
Biomarkers of exposure and effects in living organisms.	66	69	72	72
Urban radioecological hydrology modelling in (post)-emergency conditions.	65	60	62	60

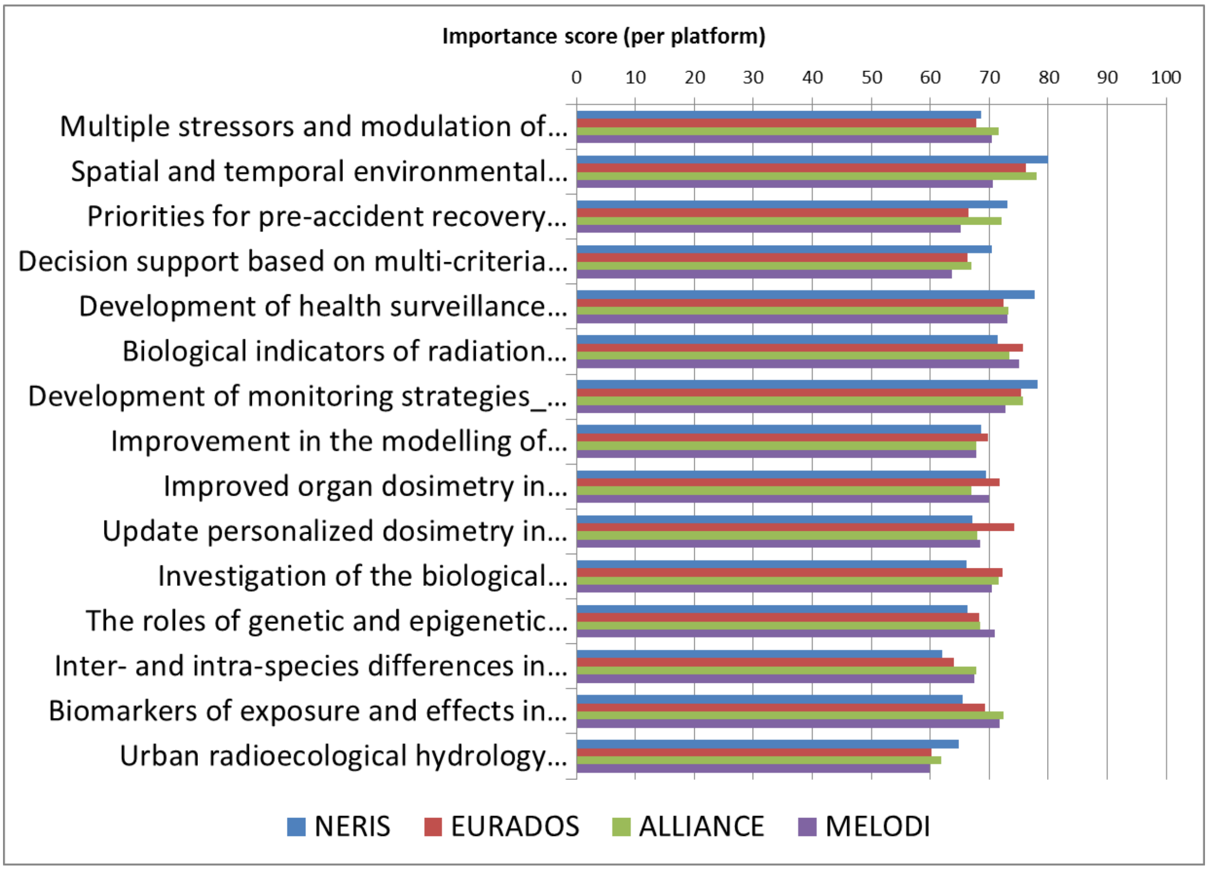


Figure 2: Opinion of different platforms about the importance of synergistic research topics

Conclusion:

With a range of average importance scores of 61-74 (fig 1) and standard deviations around 20, the importance scores do not identify any of the topics of being of greater importance in the opinion of those surveyed.

<u>Importance evaluated by platform</u>

As depicted in Figure 3, the topic “Spatial and temporal environmental modelling and human dose assessment after a nuclear accident” was scored at the top by 3 platforms. This topic considered as the most important by the respondents from the NERIS was also identified as most important by EURADOS (see figure 4) and ALLIANCE (see figure 5) members. The research themes linked to this topic were:

1. *To "develop time and space dependent models to assess the evolution of radioactivity and related dose to man dynamically from regional scale to local scale, the latter being relevant for farmers and farmer communities.*
2. *To develop countermeasure strategies at local level and,*
3. *To develop dose reconstruction techniques to infer doses and contamination for past days of a long lasting release and in this way improve the DSS.*

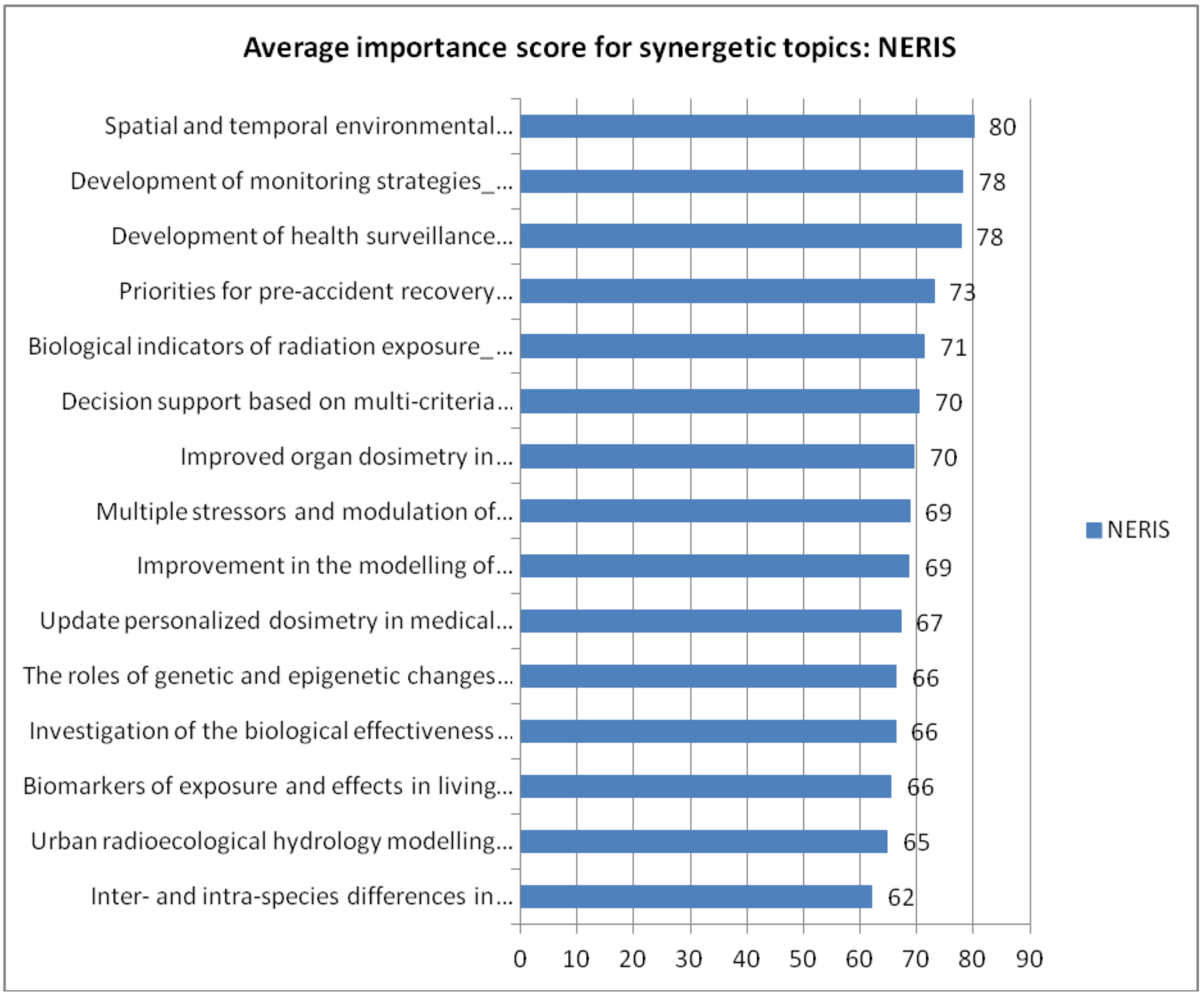


Figure 3: Ranking of average importance score for synergistic research topics: NERIS

According to the opinion of EURADOS members, the research topic “Biological indicators of radiation exposure, effects, health risk and disease susceptibility to inform emergency management and epidemiological studies” is also ranked with highest importance (see figure 4). This research topic was introduced with following justification: *"Biological indicators of radiation exposure and effects, particularly in relation to health play an important role in emergency management and can be integrated into epidemiological studies of risk and susceptibility. Identification of new and further validation of existing biomarkers in relation to dose and relationship to health is required. For emergency use simple and rapid methods will be of greatest benefit".*

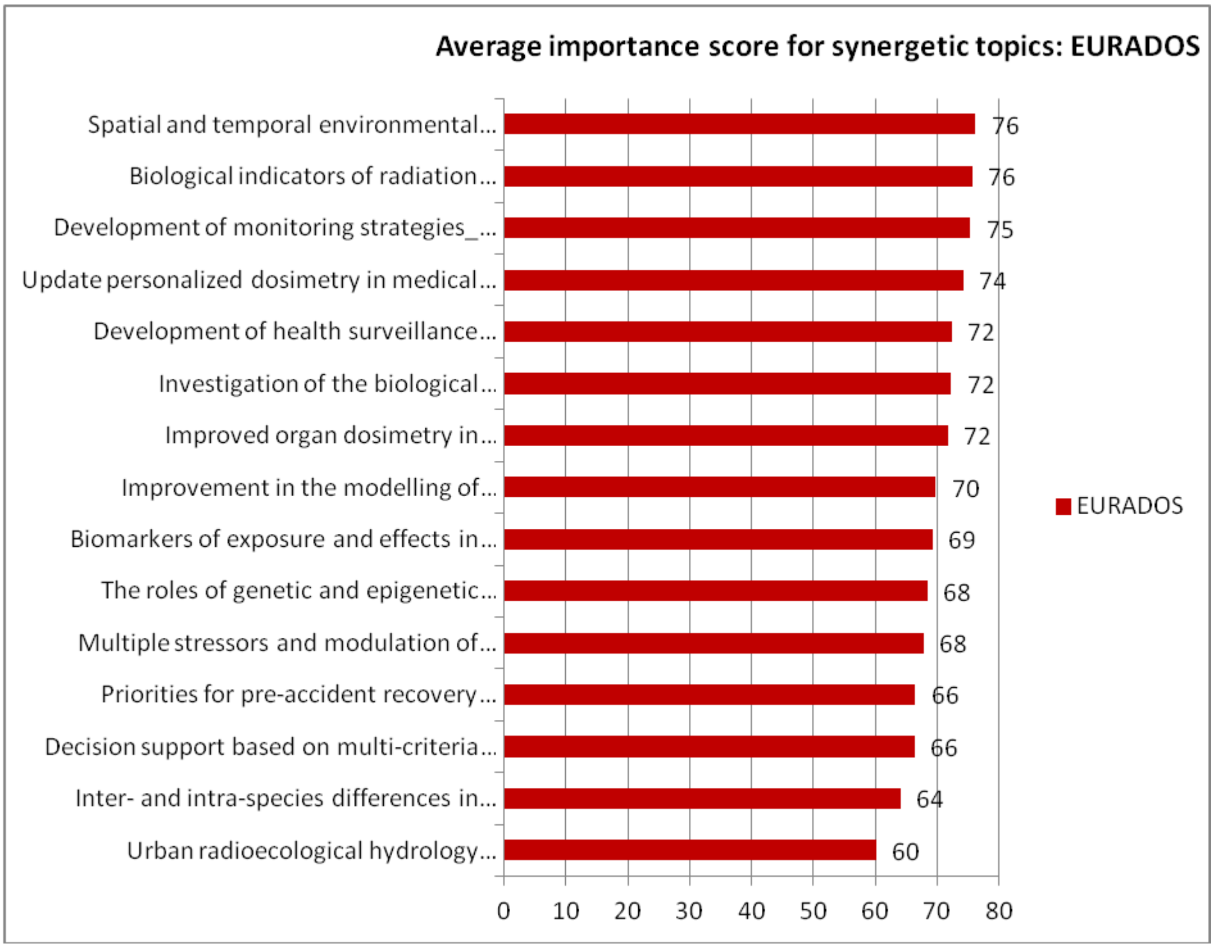


Figure 4: Ranking of average importance score for synergistic research topics: EURADOS

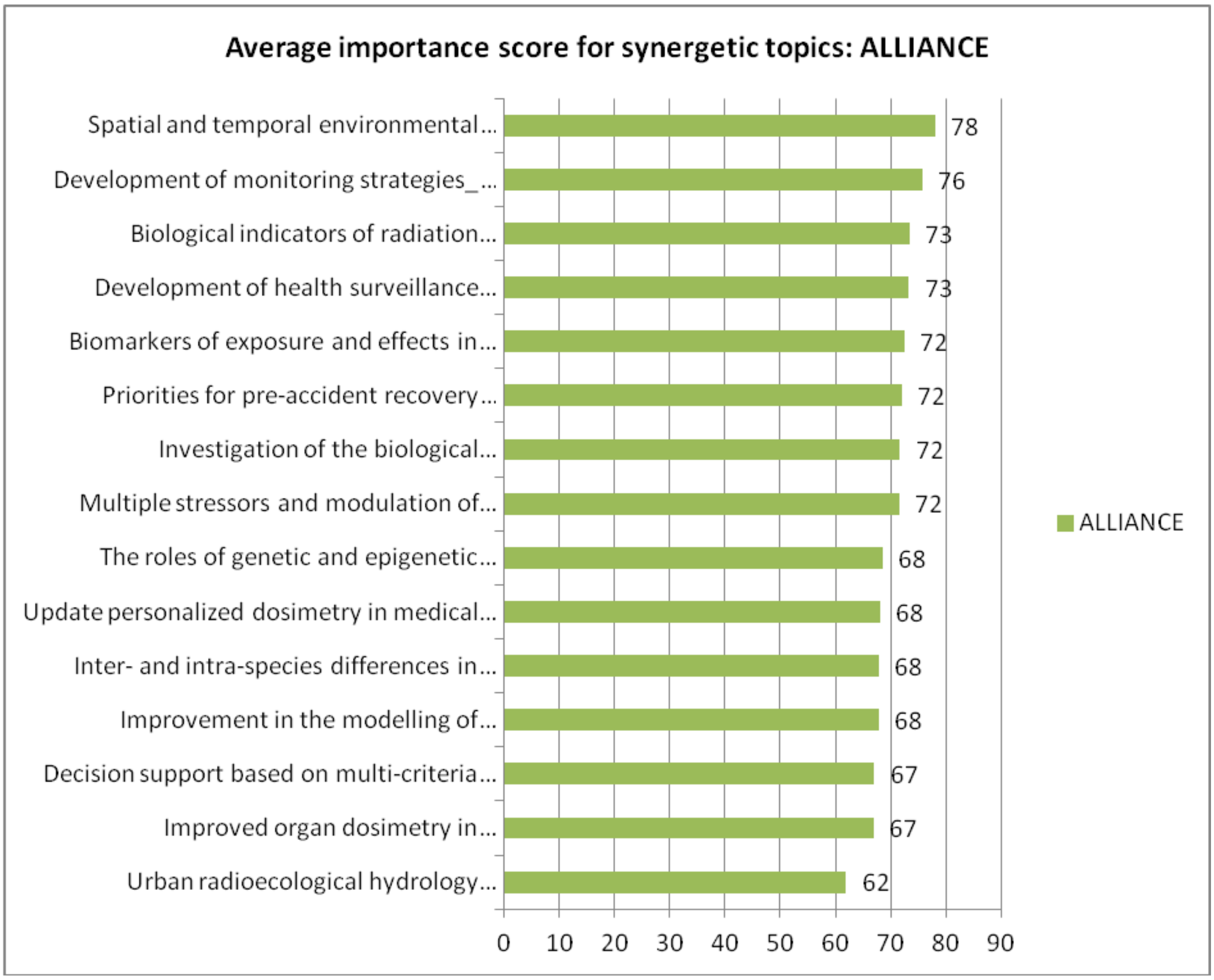


Figure 5: Ranking of average importance score for synergistic research topics: ALLIANCE

NERIS respondents identified “Spatial and temporal environmental modelling and human dose assessment after a nuclear accident” as the most important topic; both “Development of health surveillance procedures” and “Development of monitoring strategies, processes and tools” received the second highest score tie. Similarly, EURADOS respondents selected two topics as the most important: “Spatial and temporal environmental modelling and human dose assessment after a nuclear accident” and “Biological indicators of radiation exposure, effects, health risk and disease susceptibility to inform emergency management and epidemiological studies”. The second preferential choice was “Development of monitoring strategies, processes and tools”. “Spatial and temporal environmental modelling and human dose assessment after a nuclear accident”, “Development of monitoring strategies, processes and tools” and “Biological indicators of radiation exposure, effects, health risk and disease susceptibility to inform emergency management and epidemiological studies” were chosen among ALLIANCE respondents as the first three respectively. MELODI respondents identified the topic “Biological indicators of radiation exposure, effects, health risk and disease susceptibility to inform emergency management and epidemiological studies” as the one having the highest importance. Two other topics were recognised by the MELODI members as being almost as important as the first ranked topic. The first is “Development of health surveillance procedures” , i.e. to draw lessons from Chernobyl and Fukushima situations; to develop procedures for health surveillance in a broader perspective of improving living conditions of affected populations, including sampling of population and dose reconstruction, and involvement of stakeholders; and to ensure the maximum information is obtained to refine current health risk estimates and clinical decision making. The second important research topic identified by the MELODI members was “Development of monitoring strategies, processes and tools” to improve methods and tools to enhance the efficiency of monitoring strategies. The aim is to produce a complete and consistent picture of the radiological situation during a nuclear emergency response and recovery. This includes among others the development and the optimization of new and existing resources such as mobile units, trans-border information exchange, laboratory networking, dose assessment techniques. Furthermore, it also includes the development of sound methods for extracting dose parameters for decision making from all available measurement data, i.e. environmental radiological data and exposure/contamination measurements of the affected population; and measurements by expert teams and performed by the public. Improved guidelines on monitoring strategies will be derived.

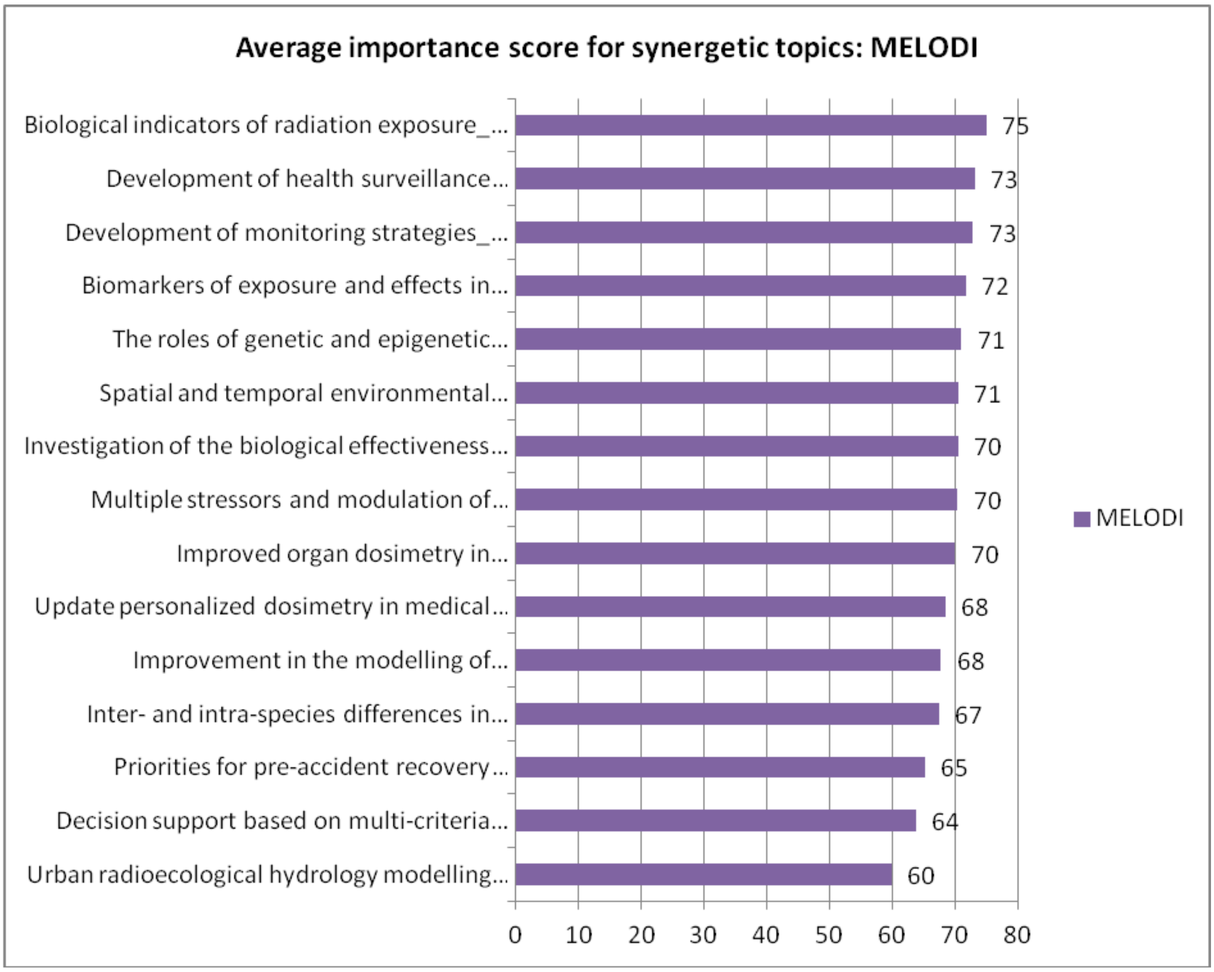


Figure 6: Ranking of average importance score for synergistic research topics: MELODI

3.2.2 Feasibility of selected research topics per platform

The average feasibility scores across all respondents range from 49 (multiple stressors) to 68 monitoring strategies (table 1), again with high standard deviations, around 20. Although the range is larger for feasibility than importance, the available data again suggest that on average there is little difference in the perceived feasibility to address the topics in the opinion of those responding.

The research topic "Development of monitoring strategies, processes and tools" was recognised as the most feasible research topic by members of all platforms: NERIS, EURADOS, ALLIANCE and MELODI.

For members of the NERIS and ALLIANCE platforms the second most feasible research topic was "Spatial and temporal environmental modelling and human dose assessment after a nuclear accident". For members of EURADOS and MELODI the second most feasible topic was the "Update personalized dosimetry in medical applications" with the following objective: "*an integrated personalized dosimetry in medical applications that can be used as input for low dose research. This can be done by improving (1) internal microdosimetry in radiotherapy and medical imaging, (2) patient dosimetry in interventional radiology and CT examinations (3) out-of-field dosimetry for photon and particle therapy*".

All four platforms members considered the topic “Multiple stressors and modulation of radiation effects in living organisms” as the least feasible (see Table 3). The respondents evaluated that the following research objectives have relatively low feasibility: "*to elude mechanisms explaining how and to what extent radiation effects in organisms are modulated by the context of multiple stressors potentially present in the environment (e.g., chemicals, pathogens). Faced to the multitude of stressors in field, to develop a mode-of-action based approach for identifying stressors combinations likely to interact with ionising radiation, taking account for the biological specificities of the organism studied that vary among species*".

Table 3: Average feasibility score for synergistic topics per platform

Feasibility of research topic/number of submitted eSurveys per platform (score 1-100)	NERIS	EURADOS	ALLIANCE	MELODI
Multiple stressors and modulation of radiation effects in living organisms.	43	48	45	48
Spatial and temporal environmental modelling and human dose assessment after a nuclear accident.	73	68	71	64
Priorities for pre-accident recovery preparedness.	69	67	68	64
Decision support based on multi-criteria decision aiding tools in the various phases of an emergency (including the post-emergency remediation phase).	62	62	61	59
Development of health surveillance procedures.	72	68	69	66
Biological indicators of radiation exposure, effects, health risk and disease susceptibility to inform emergency management and epidemiological studies.	54	58	55	59
Development of monitoring strategies, processes and tools.	76	72	75	69
Improvement in the modelling of biokinetics and dosimetry of internal emitters.	61	61	62	62
Improved organ dosimetry in epidemiological studies.	57	61	60	61
Update personalized dosimetry in medical applications.	69	70	69	67
Investigation of the biological effectiveness of different radiation qualities and prediction of biological risks.	57	61	59	61
The roles of genetic and epigenetic changes in heritable/transgenerational and somatic effects relevant to individual and population health.	48	51	53	55
Inter- and intra-species differences in radiosensitivity.	46	50	52	52
Biomarkers of exposure and effects in living organisms.	49	55	54	56
Urban radioecological hydrology modelling in (post)-emergency conditions.	64	62	65	59

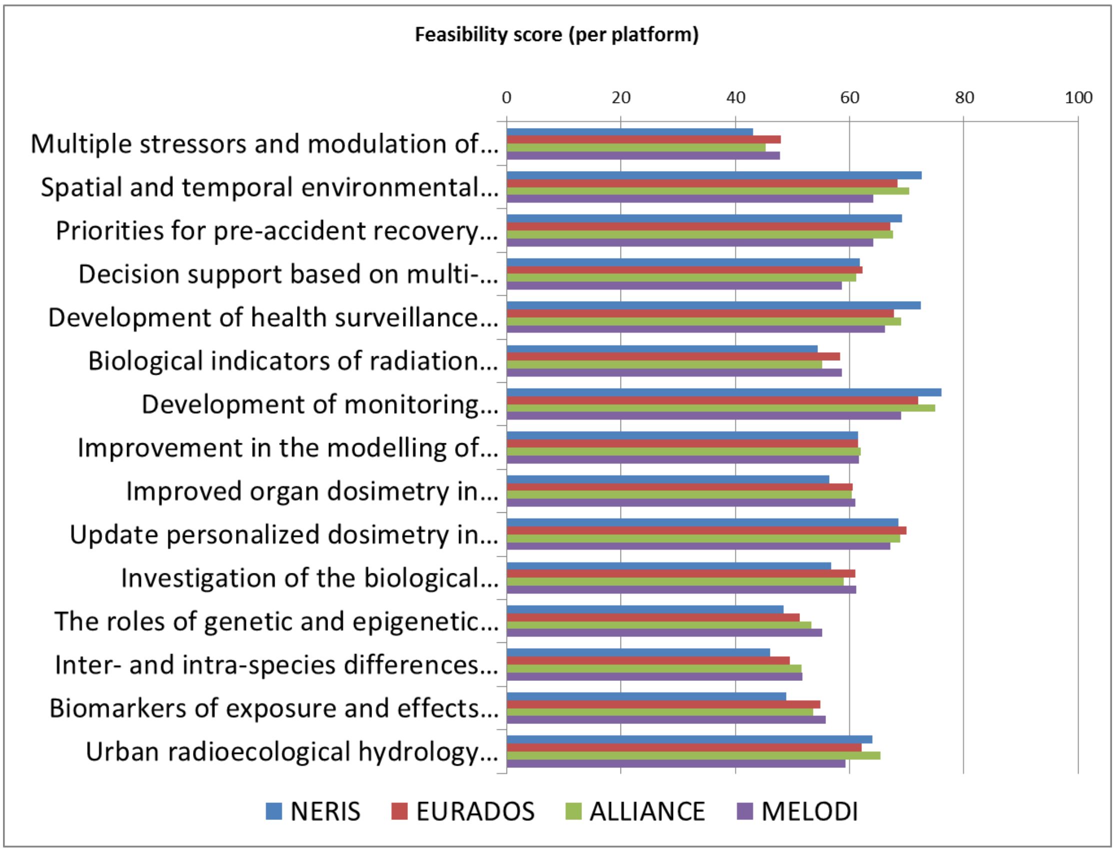


Figure 7: Opinion of different platforms about feasibility of research topics

The following figures (figures 8-11) show the ranking of different research topics per platform with respect to the feasibility of the topic.

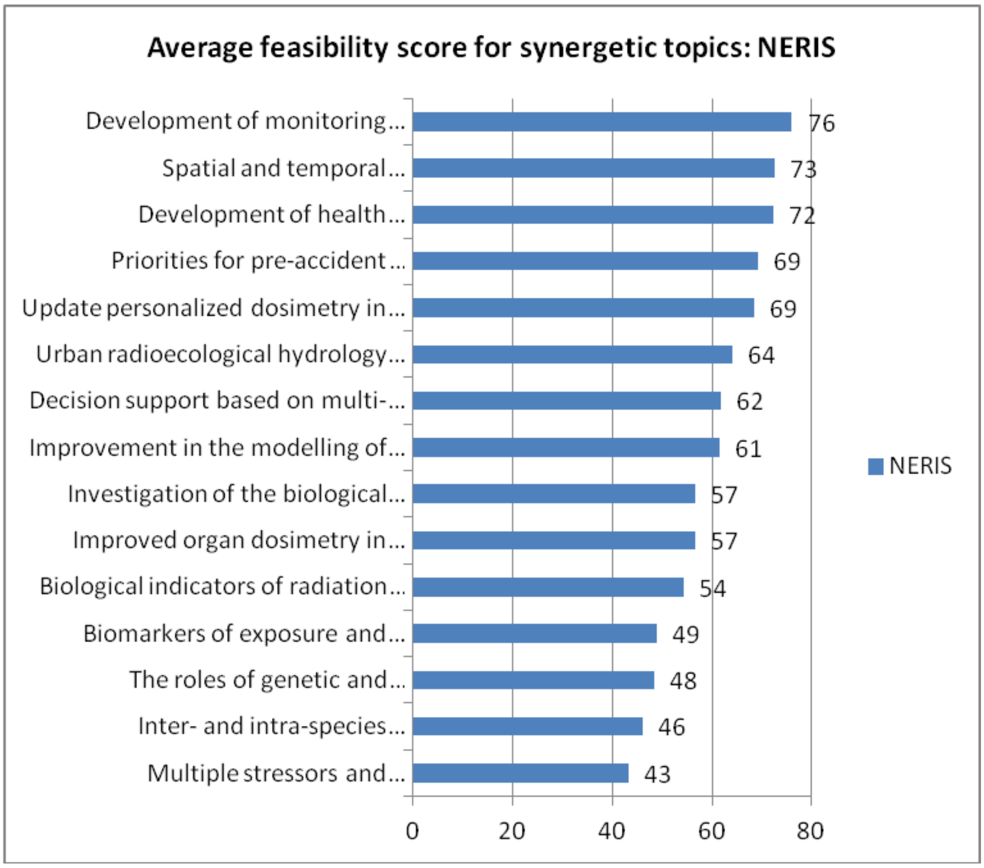


Figure 8: Ranking of average feasibility score for synergistic research topics: NERIS

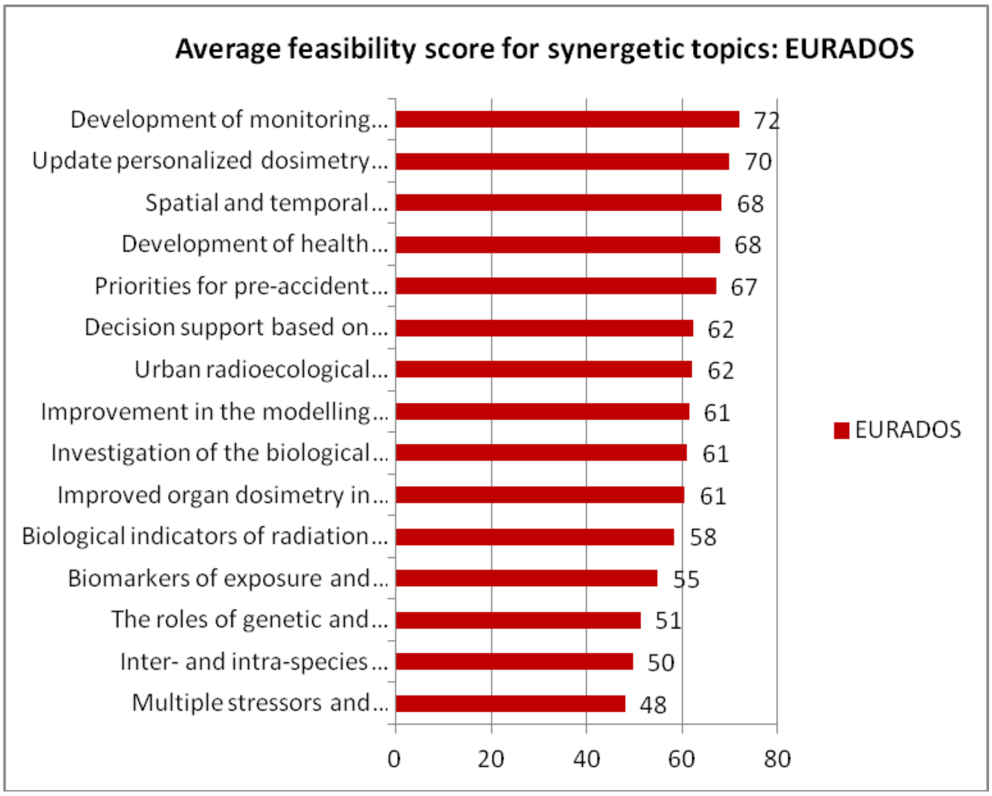


Figure 9: Ranking of average feasibility score for synergistic research topics: EURADOS

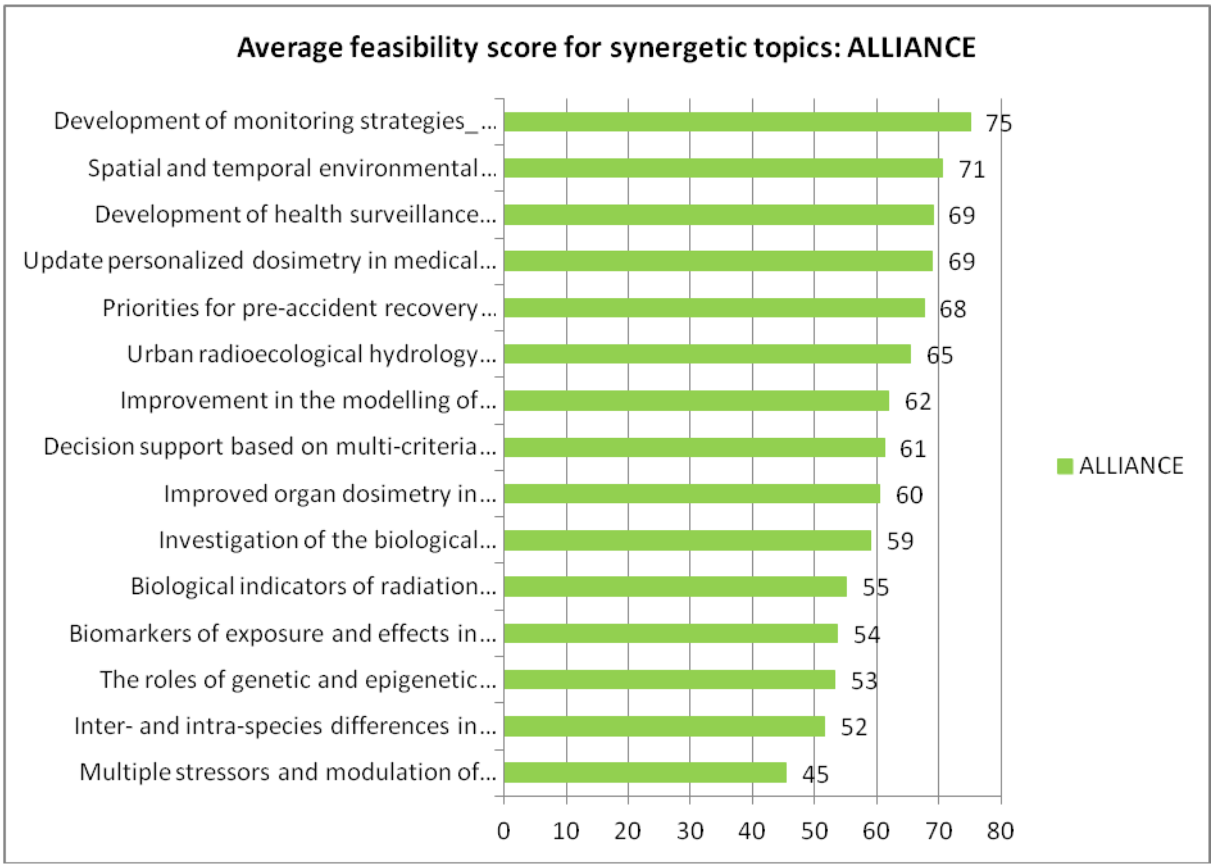


Figure 10: Ranking of average feasibility score for synergistic research topics: Alliance

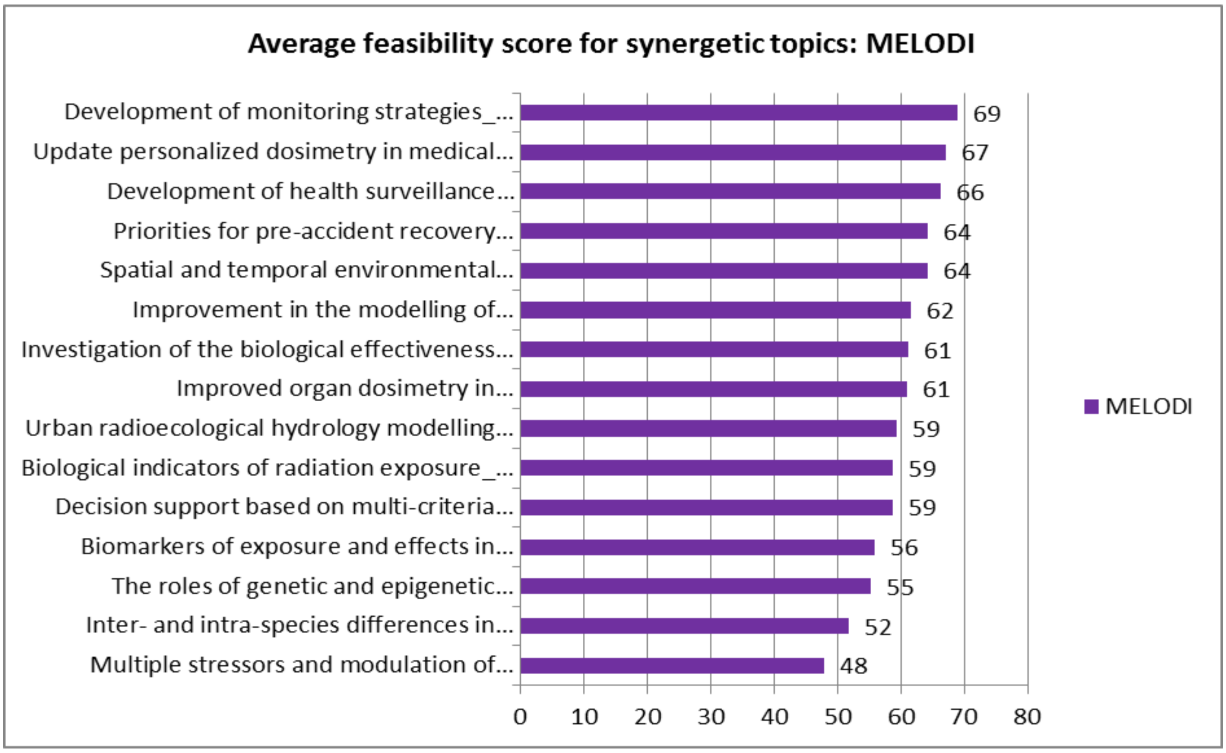


Figure 11: Ranking of average feasibility score for synergistic research topics: MELODI

Conclusion:

While there was a greater range in the average scores given in respect of perceived feasibility (49-68) by comparison with perceived importance (61-74), the standard deviation was high, around 20. The high variation again makes it difficult to make clear and robust judgements on the relative feasibility of the topics

3.2.3 Other research topics proposed by stakeholders

Respondents were asked to indicate specific areas/projects that they consider to be particularly promising to foster effective inter-disciplinary synergy. On this open question we received approx. 70 answers; suggestions for areas and projects and also comments and views related to previously evaluated topics.

The open question was formulated as follows:

“Are there specific areas/projects that you consider to be particularly promising to foster effective inter-disciplinary synergy?”

The answers could be categorised as:

1. Answers highlighting one of the synergistic topics proposed in the questionnaire or a combination thereof, or highlighting the importance of some basic research domains in exact sciences (Type 1 answers: ~85%).
2. Answers expressing the importance of political and social sciences, and the interaction with stakeholders (Type 4 answers: (~5%).
3. Answers on the importance to interact with the medical world (both non-nuclear and medical application oriented) (Type 3 answers: ~5%).
4. Answers giving advice on how the research in radiation protection should be organised (Type 4 answers ~5%).

1. Answers highlighting one of the synergistic topics proposed in the questionnaire, or paying attention to the importance of some basic research domains in exact sciences

The majority of answers are expressing an advice on which topic of the synergistic list is the most important, or which part of a topic in the priority list deserves a high priority. As this is analysed in other sections of the document we do not comment further here.

However, some cross-cutting areas of research are mentioned as a priority:

- Methodology and metrology of experiments (eg. standardisation, validation).
- Infrastructure: high quality biobanks (from occupational and medical origin) with precise dosimetry.
- Mathematic modelling and uncertainty analysis techniques.

2. Answers expressing the importance of political and social sciences, and interaction with stakeholders

Various answers point out that it would be worth to take on board scientists with a background in sociology and politics. In addition, psychological consequence of decisions taken in emergency situations, and risk perception in normal operation and in emergency situations are stated to be important issues. Psychological stress is also considered in one response to be an important factor in multiple stressor analysis research.

Furthermore, decision support systems are considered in one answer as tools to facilitate communication to decision-makers, public and media in the framework of radiological emergency.

Finally, it is mentioned that it is important to work on general public awareness programs regarding radiation risk and protection.

3. Answers on the importance to interact with the medical world

The interaction with the medical world was considered by some to be beneficial for both the world of radiation protection and the medical world.

In one answer, it is stated that under the last EU FP7 programme, several networks and research programmes have produced knowledge and evidence with high potential benefits in the field of the protection of patient and staff from the exposure to ionising radiation. Analogously, other answers state that RP research findings might improve decisions in the field of therapeutic planning, radiological emergency and justification of exposure.

Vice-versa, expertise from the medical world is of interest to the radiation protection research community. Medical expertise is indispensable in various synergistic topics listed in the e-Survey. Various answers emphasise the importance of physical and psychological health effects in emergency and non-emergency cases.

4. Answers giving advice on how the research in radiation protection should be organised

General advices on how research in radiation protection should be organised are also collected in the open questions. For example, a respondent states that the research should prioritise on estimating the risk of major issues that underpin the whole system of radiation protection, solving questions of the society, such as “what is the risk of circulatory disease at low dose / dose rates”, or “how valid is the use of the LNT model in low dose / dose rate risk estimation”.

Others emphasise to focus on basic areas first, such as unravelling genetic pathways, signalling processes and physical modelling.

In one answer it is stated that interdisciplinary synergies could be enhanced by trying to improve the coordination between the monitoring of environmental contamination and population's health and the modelling of doses and environmental transfers.

Another remark was that many of the priorities are focused on accidents, whereas the majority of radiation protection work relates to normal operating conditions and planning situations.

3.3 FOCUS AREA(S)

The OPERRA survey aimed at collecting information from many areas relevant to radiation protection. The respondents were asked to choose one or more focus area(s) for more detailed scientific questions. They could select one or more following areas: Radioecology (ALLIANCE), Emergency and recovery preparedness (NERIS), Low dose risk (MELODI), Dosimetry (EURADOS), Ethics, Risk communication and risk perception and Education and Training.
The largest number of selections of specific focus areas was recorded for the Low dose risk focus area (124), followed by Dosimetry (120), Education and training (104), Risk communication and risk perception (91) and Radioecology (88). Fewer selections were recorded for the Emergency and recovery preparedness focus area (66) and ethics (50).

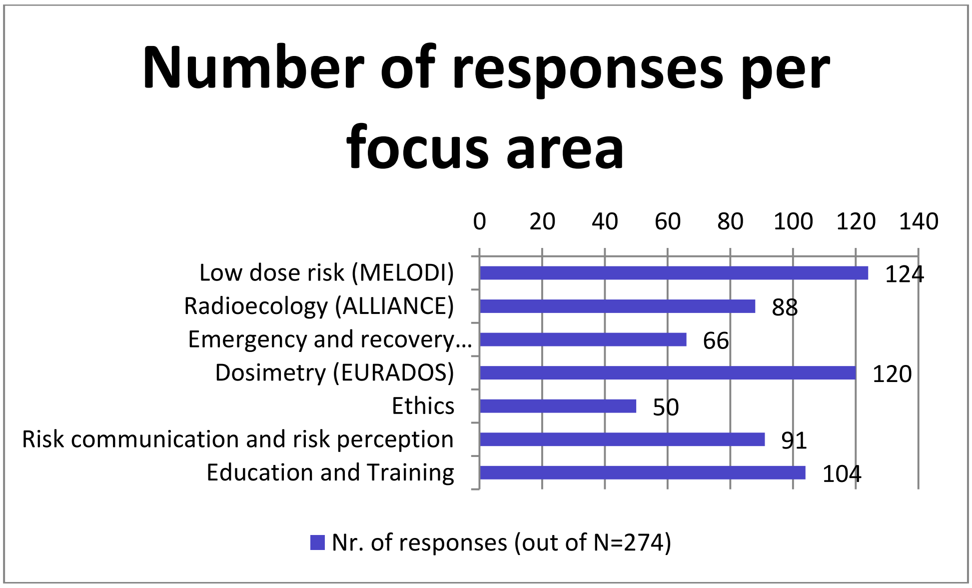


Figure 12: Number of responses per focus area

The interest in the focus areas reflects the importance of supporting not only the research areas that are already covered by platforms and associations as for instance MELODI and EURADOS, but also the areas that were included in the e-survey on the OPERRA initiative and relevant to radiation protection. These areas are education and training, risk communication and risk perception and ethics. However this issue is difficult to be interpreted properly: for example, the Strategic Research Agenda of the ALLIANCE clearly encompasses risk communication and perception as part of research lines in one of the 3 major constituting challenges. This area is also clearly of importance for the NERIS platform; similarly, Education and Training is clearly supported by all the platforms.

3.4 LOW DOSE RISK STRATEGIC RESEARCH AREA

Respondents were asked to evaluate the importance and feasibility of different topics related to 1. Radiation-induced cancer; 2. Radiation-induced non-cancer diseases and 3. Individual and general health and radiation protection. The topics were selected by the MELODI platform.

3.4.1 Radiation-induced cancer

The most important topics related to radiation-induced cancer were considered the "Biomarkers for radiation exposure, effects and disease: identification, development and validation" and the "Risks associated with internal contamination with radionuclides".

Table 4: Means and standard deviations in answers related to radiation induced cancer effects research topics

Radiation induced cancer		Mean	Std. dev
Suitable cohorts of radiation exposed populations for molecular epidemiological studies related to cancer effects: identification, establishment and continued follow-up	Feasibility Importance	60 74	22 21
Biomarkers for radiation exposure, effects and disease: identification, development and validation.	Feasibility Importance	62 77	19 19
Development and use of suitable whole animal and human cellular models (including somatic stem cells) to study quantitative and mechanistic aspects of radiation carcinogenesis.	Feasibility Importance	61 72	21 23
Impact of low dose and low dose rate radiation effects on pathways/processes contributing to carcinogenesis.	Feasibility Importance	61 74	22 21
Risks associated with internal contamination with radionuclides.	Feasibility Importance	65 77	21 17
Identification of the nature and number of target cells at risk for specific cancers in humans	Feasibility Importance	55 70	21 22

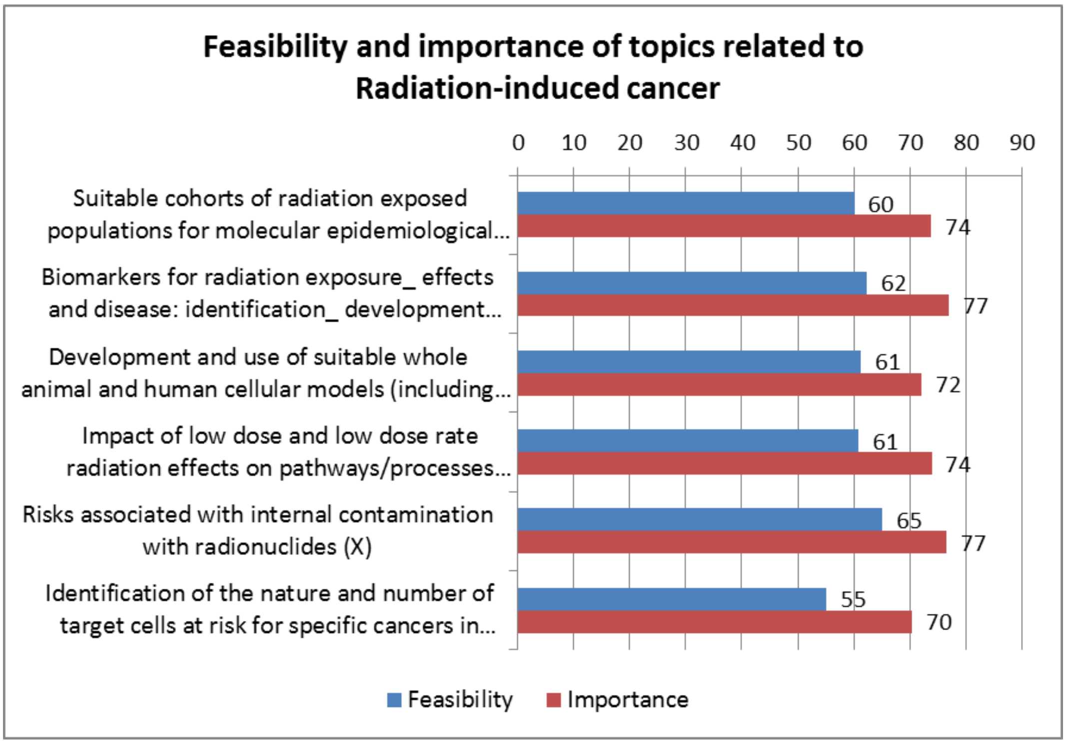


Figure 13: Feasibility and importance of topics related to radiation induced cancer

Conclusion:

The ranges and standard deviations in importance and feasibility scores do not allow clear judgements to be made on the priority topics in the opinion of those surveyed.

Table 5: Additional issues related to radiation-induced cancer suggested by respondents

	MELODI: Radiation-induced Cancer
	Are there any additional issues related to radiation-induced cancer you would like to suggest as a priority? Please specify.
	Comments: 23
1	Is the Linear No Threshold assumption valid?
2	It is from my own and personal opinion that cells and animals models to elucidate radiation- cancer issue should not be based in low doses. Where the stochastic nature of the event make difficult interpretation.
3	Microenvironment and impacts at the system level
4	Integration of molecular epidemiology in models of carcinogenesis in order to derive improved risk estimates
5	Numerical modelling and tissue experiments for the early stage of carcinogenesis.
6	Studies on second cancers among patients under radiation treatments
7	Comparison of different types of Radiation for induction of cancer
8	Interconnection of DNA-damage responses and inflammation. Individual radiosensitivity.
9	Comparison of different types of radiation for induction of cancer
10	1. Epidemiological assessment of very low dose in highly exposed cohorts. One example is lung transplants in mucoviscidosis: cohort of around 150 patients in one institution (each patient with an average of more than 100 chest X-rays and 15 – 20 CTs; very well medically followed. some of them over 10y follow up; of course one local cohort is too small but might contribute to a European network around some significant clinical situations frequently imaged. Aside mucoviscidosis. Scoliosis is another example.) 2. Patient dosimetry and protection in high dose procedures (interventional) and CT. with emphasis on skin and organ dose evaluation. Including the effect of newer methods to improve image quality while reducing patient doses. e.g. low electronic noise detectors with highly integrated readout electronics or photon counting detectors and novel image reconstruction schemes for reconstruction accurate low-noise image data from very noisy (lowdose) raw data. As well as risk assessment and risk communication. 3. Approaches to improve occupational protection (with emphasis on lens and extremity dose estimation and protection) in interventional and nuclear medicine procedures. 4. Realistic determination of extremity/finger dose in interventional radiology/cardiology and nuclear medicine. We know from the ORAMED project that a significant number of medical professionals exceeds the annual BSS dose limit of 500 mSv but an insufficient or missing dosimetry does not show these high doses. The increasing use of 18F in PET/CT and 90Y in radioembolization of the liver (SIRT) are two examples for higher occupational exposures in future. For harmonized EU-wide regulations. Medical associations could develop recommendations to the regulatory boards to avoid different or missing national regulations how many dosimeters and which type are mandatory. where to wear them and for which procedures.
11	Conducting studies for human is of particular interest but we should not forget non-human organisms.
12	Exposures early in life and their persistence - factors that influence both progression and regression of the persistence of molecular and cellular damage leading to cancer.
13	LET of Radiation
14	The role of tissue and cancer stem cell in the development of radiation-induced cancer and the molecular pathways involved. Currently it is possible to culture tissue (adult) stem cells of many tissues. This provides unprecedented opportunities to study the effects of low dose irradiation on the in vitro and in vivo response of these cells and potential carcinogenesis. It is warranted to take action and use these models now. Some scientist involved in the development of these models are even working in the field of radiation biology.
15	Define age window for radiation sensitivity of different radiation induced cancers also by in vitro experimental studies. Define the exact mechanisms behind.

16	Investigation of reasons for inter-individual differences in radiation sensitivity. Whether that be linked to differences in radionuclide metabolism. DNA repair.
17	Determination of ion-cluster-size distributions.
18	Secondary Cancers after Radiotherapy
19	Mixed exposures : identification. assessment
20	Use of GM animals to investigate radiation-induced cancer response. This could provide a sensitive model and give information on thresholds for cancer induction.
21	Children.
22	None of the questions specifically ask about the issues of DDREF or risk extrapolation model.
23	Study of mechanisms underlying individual sensitivity.

3.4.2 Radiation-induced non-cancer diseases

In general the topics related to radiation-induced non-cancer diseases received higher average scores in terms of importance than of feasibility. All topics received very similar feasibility scores, with the exception of the topic “Identification of the nature and number of target cells at risk for specific cancers in humans” which was evaluated as somewhat less feasible than the rest of the suggested topics.

Table 6: Means and standard deviations in answers related to non-cancer effects research topics

Non Cancer effects		Mean	Std.
Suitable cohorts of radiation exposed populations for molecular epidemiological studies related to non-cancer effects: identification_ establishment and continued follow-up	Feasibility Importance	60 75	21 20
Biomarkers for radiation exposure_ effects and disease: identification_ development and validation	Feasibility Importance	60 75	21 19
Development of suitable whole animal models to study quantitative and mechanistic aspects of non-cancer diseases	Feasibility Importance	60 71	22 21
Impact of low dose and low dose rate radiation effects on pathways/processes contributing to non-cancer diseases	Feasibility Importance	59 72	22 21
Risks of non-cancer diseases following internal contamination with radionuclides	Feasibility Importance	57 69	22 21
Identification of the nature and number of target cells at risk for specific non cancer diseases in humans	Feasibility Importance	54 67	20 19

The feasibility and importance of “Suitable cohorts of radiation exposed populations for molecular epidemiological studies related to cancer effects: identification, establishment and continued follow-up” as well as the topic “Biomarkers for radiation exposure, effects and disease: identification, development and validation” were assessed by 119 respondents. Both topics received high scores for importance (75) and medium for feasibility (60). These two topics were evaluated as the most important ones, and at the same time as feasible as the others.

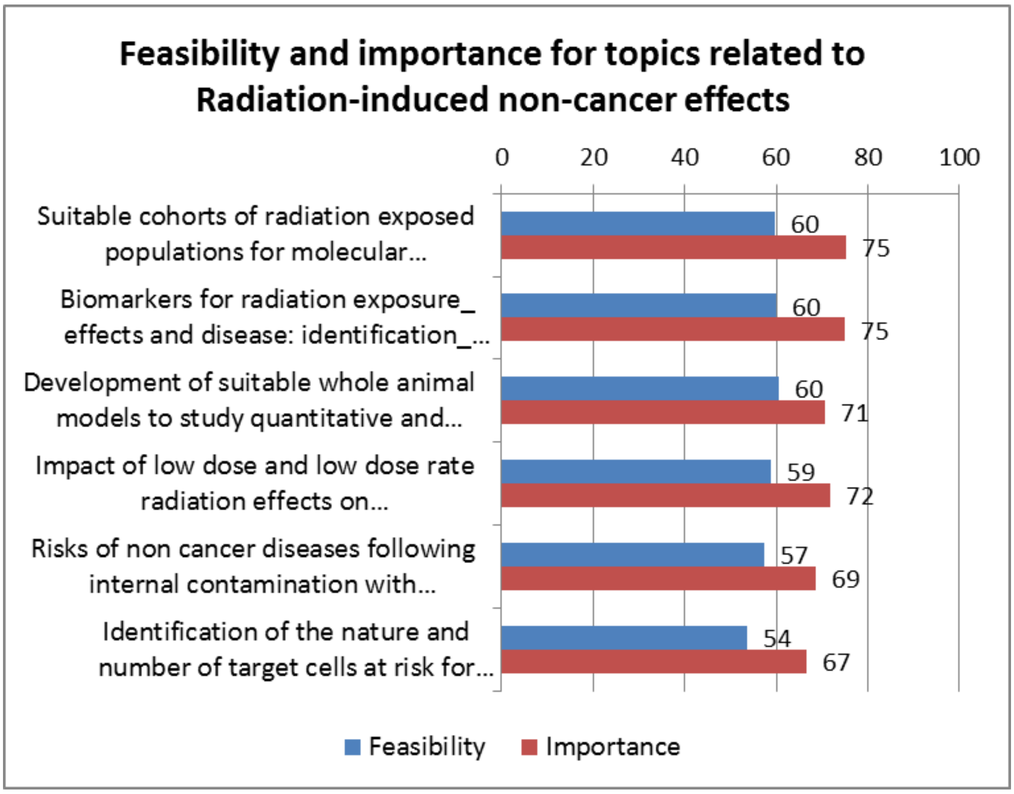


Figure 14: Feasibility and importance for topics related to radiation-induced non-cancer effects

Conclusion:

The ranges and standard deviations in importance and feasibility scores do not allow clear judgements to be made on the priority topics in the opinion of those surveyed.

Table 7: Additional issues related to radiation-induced non cancer suggested by respondents

	MELODI: radiation-induced non cancer diseases
	Are there any additional issues related to radiation-induced non cancer diseases you would like to suggest as a priority? Please specify.
	Comments: 19
1	I would anticipate major problems in obtaining statistically significant results. But don't profess to be an expert in this field.
2	System level effects such as bystander effects and multiple stressors.
3	Tissue experiments.
4	Therapeutic Radiation doses vs low Radiation doses
5	Resolution of inflammation by low dose exposure.
6	Therapeutic radiation doses versus low radiation doses
7	Effects on Heart. Brain
8	I don't think this is a promising topic in the low dose irradiation field. in the high dose region however this may be relevant.
9	Area of interest: Cardiovascular system. Central nervous system. Reproductive function
10	Develop studies in specific areas such as central nervous system. Cardiovascular system and reproductive function.
11	Cardiovascular system. Nervous system. Reproduction function.
12	Area of interest: Cardiovascular. Neurodisease. Reproductive function. Hematology.
13	Immune and hematopoietic system are essential to be studied in this field of low-dose radiation.

14	Priority to define the nature of target cells is very high. but to define the number of target cells is highly difficult.
15	Cardiovascular system. Central nervous system. oxidative stress
16	Mechanisms of Development of Radiation. Lesions in Critical Organs. Radiation Induced Multiply Organ Dysfunction Syndrome
17	So far limited morbidity data / registers available on non cancer diseases/disorders
18	Radiation-induced cataracts - if the lens is one of the most radiosensitive tissues in the body (Ainsbury et al.) why are relatively few cataracts produced? Is there a difference between x-ray and UV induced cataracts? UV exposures are much more common but there does not appear to be much research undertaken in this area.
19	Cardiovascular. Central nervous system

3.4.3 Individual and general health and radiation protection

Table 8: Means and standard deviations of answers related to individual and general health and radiation protection issues

Radiation protection issues		Mean	Std.
Impact of inter-individual variation of radiation risks for cancer and non-cancer diseases and on dose response relationships in populations.	Feasibility Importance	54 77	21 18
Contribution to the development of radiation-associated diseases of radiation effects in target cells_ the tissue environment_ and their interaction at different dose levels.	Feasibility Importance	58 73	19 18
Impact of low dose and low dose rate radiation effects on immune function.	Feasibility Importance	59 72	21 20
Effect of gender and/or age-at-exposure on radiation risk.	Feasibility Importance	68 76	19 16
Trans-generational and heritable radiation effects.	Feasibility Importance	55 69	23 24
Synergistic effects of combined exposure with environmental pollutants.	Feasibility Importance	51 74	23 20

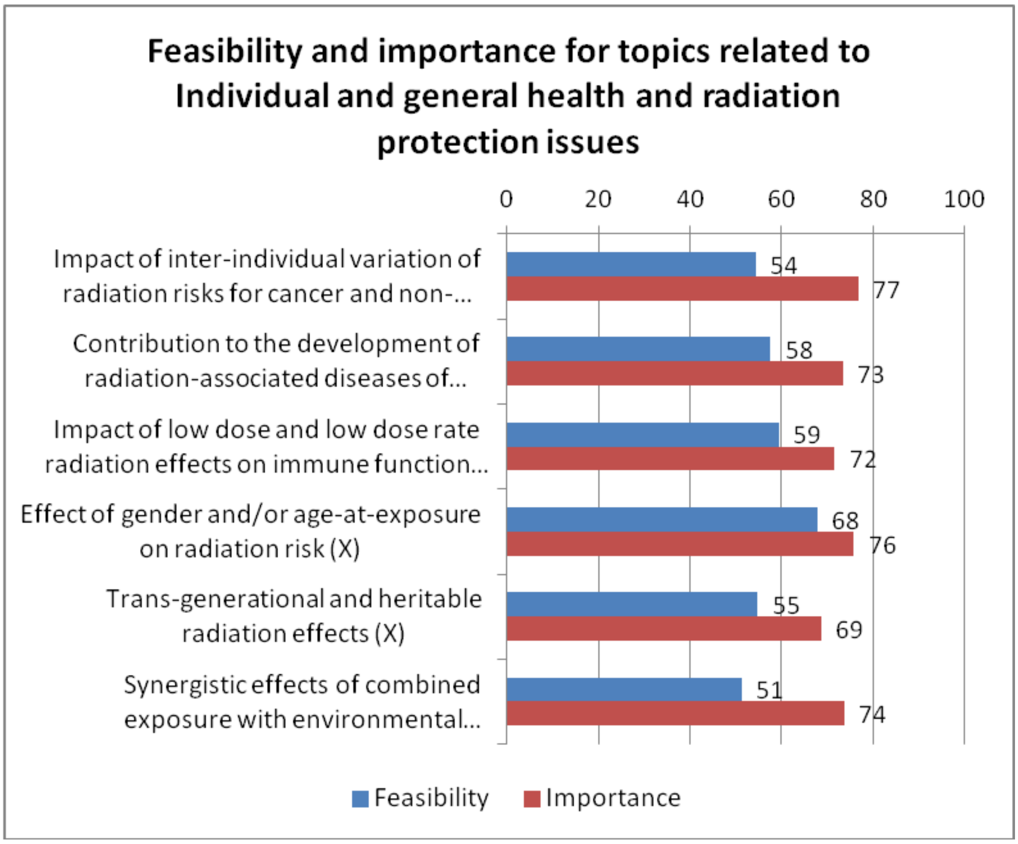


Figure 15: Feasibility and importance for topics related to individual and general health and radiation protection issues

Conclusion:

The ranges and standard deviations in importance and feasibility scores do not allow clear judgements to be made on the priority topics in the opinion of those surveyed.

Table 9: Additional issues related to individual and general health and radiation protection suggested by respondents

	MELODI: Individual and general health and radiation protection
	Are there any additional issues related to individual and general health and radiation protection issues you would like to suggest as a priority? Please specify.
	No of comments: 9
1	To study the effect of dose inhomogeneity and related health effects in different individuals in case of internal emitters.
2	1. Radiation exposure in assessment of treatment response (and follow-up) using standardized disease- or treatment specific protocols: Frequent and short-term treatment response imaging becomes more and more important with the use of expensive personalized therapies. To avoid excessive accumulation of dose. Research shall develop a new approach for low-dose treatment response imaging focusing on the detection of change. But still providing reliable diagnostic assessment. Novel detector technologies as well as image reconstruction methods available for reducing radiation exposure should be fully explored and exploited. 2. Radiation protection in obesity imaging (BMI-specific protocols): General and patient demographics show that as of today over 10% of the population is obese with still growing

	numbers. To achieve diagnostic imagine quality in obese patients higher than average radiation doses are required. Techniques normally used for reducing patient radiation exposure have instead to be exploited to acquire images of sufficient diagnostic quality. In order to always guarantee images of sufficient diagnostic quality at the lowest radiation exposure necessary BMI-specific protocols are required. And specific dose reduction algorithms have to be developed for obese patients. 3. Individualized patient dose and risk assessment in medical imaging with ionizing radiations. Main aims: To produce dose data using patient-specific Monte Carlo software and develop dose estimation methods based on normalized doses for all imaging procedures. Especially CT and fluoroscopically-guided interventional procedures. To assess radiogenic risks to the patient associated with the exposure from imaging protocols using data provided by European and international organizations. To perform original research using individualized-dosimetry tools from which new findings. Innovations and practical guidelines for optimal dose management of patients needing radiologic procedures will result. 4. Integrating individual IT data (electronic patient record. PACS. RIS.) for prospective radiation protection issues (dose. risk estimation) Automatic dose recording is currently available with several commercial software solutions. And hence have the potential to help establishing a large repository. However there is an urgent need for standardisation and for developing cross analysis platforms at a European level in order to establish "dynamic DRLs" and to follow highly exposed or sensitive cohorts. 5. Calculating individual patient dose and estimating consecutive cancer risk based on exposure parameters. Individual dose measurements and imaging data as well as simulation. e.g. Monte Carlo: patient-specific. Machine-specific. Indication specific. 6. Individual radiosensitivity and adapted imaging guidelines/protocols The development of tests aimed at screening highly sensitive patients to dose exposure should be completed by the development of repositories which would include all the relevant patient information for an appropriate follow-up.
3	The study of combined exposure can be very synergistic. However. First chemicals that potentially interact with radiation and when a substantial exposure can be envisioned have to be defined.
4	Internal contamination. Low doses.
5	Develop project with internal contamination studies and in the field of low dose.
6	Internal contamination. Low dose exposure.
7	Internal contamination. Low dose.
8	The multipollution context is not sufficiently taken into account in studies about internal contamination: complex mixes of radionuclides. Complex mixes of chemical pollutants and radionuclides. etc.
9	Internal contamination at low doses

The content of all low dose risk free texts is reported and summarized in annex 1 (pp 94)

3.5 RADIOECOLOGY STRATEGIC RESEARCH AGENDA

This section addresses the Radioecology Strategic Research Agenda (SRA) developed by the ALLIANCE platform in collaboration with the EURATOM STAR and COMET consortia.

The scientific discipline of radioecology provides quantitative and integrative assessments of radionuclide impacts on man and wildlife for a wide range of exposure scenarios. The need for radioecological expertise arises when evaluating the risks from, for example, nuclear power plants or disposal of nuclear wastes; in response to nuclear accidents or possible terrorist events; and in the debate on chronic, low dose effects. As such it provides science underpinning the other radiation protection areas within the OPERRA umbrella.

The Radioecology SRA has evolved and been improved through previous consultations with an array of diverse stakeholders. The SRA responds to the question: “What topics, if critically addressed over the next 20 years, would significantly advance radioecology?”

The ALLIANCE SRA was available from the Radioecology Exchange website; the version used in this e-Survey was an evolution taking into account comments received from the earlier consultations.

The Radioecology SRA prioritises three major scientific challenges facing radioecology, with the goal of improving research efficiency and advancing the science more rapidly.

First, respondents were asked whether they answered the questionnaire on the Radioecology SRA in 2012 which received 110 independent responses. 29 respondents confirmed their previous involvement in the SRA since they answered on the previous questionnaire. 59 respondents were previously not consulted.

Secondly, the respondents were asked whether they attended the Paris consultation workshop in November 2012: 14 respondents attended the conference and 74 did not.

3.5.1 Strategic vision of Challenge 1: To Predict Human and Wildlife Exposure in a Robust Way by Quantifying Key Processes that Influence Radionuclide Transfers and Expo

Over the next 20 years radioecology will have achieved a thorough mechanistic conceptualisation of radionuclide transfer processes within major ecosystems (terrestrial, aquatic, urban), and be able to accurately predict exposure to humans and wildlife by incorporating a deeper understanding of environmental processes.
The respondents were asked to indicate the importance and feasibility (i.e how difficult will it be to achieve them over the next 20 years) of achieving each of these research lines which are grouped below by the challenge that they address.

- Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife.
- Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides.
- Develop transfer and exposure models that incorporate physical, chemical and biological interactions, and enable predictions to be made spatially and temporally.
- Represent radionuclide transfer and exposure at a landscape or global environmental level with an indication of the associated uncertainty.

Table 10: Means and standard deviations in answers related to radioecology - challenge 1 - To Predict Human and Wildlife Exposure in a Robust Way by Quantifying Key Processes that Influence Radionuclide Transfers and Expo.

Challenge 1		Mean	Std.
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife.	Feasibility	66	19
	Importance	80	15
Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides.	Feasibility	64	21
	Importance	80	15
Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally.	Feasibility	58	22
	Importance	80	16

Represent radionuclide transfer and exposure at a landscape or global environmental level with an indication of the associated uncertainty.	Feasibility	61	20
	Importance	74	18

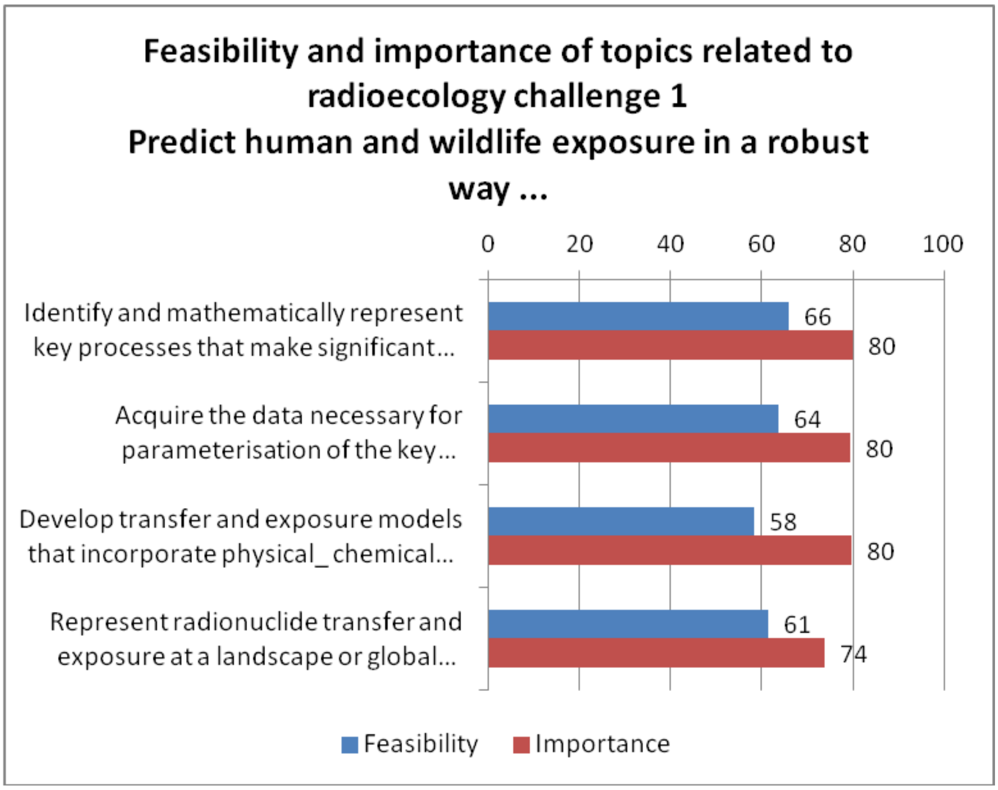


Figure 16: Feasibility and importance for topics related to radioecology –Challenge 1: To Predict Human and Wildlife Exposure in a Robust Way by Quantifying Key Processes that Influence Radionuclide Transfers and Exposure.

3.5.2 Strategic vision of Challenge 2: To Determine Ecological Consequences under Realistic Exposure Conditions

Over the next 20 years radioecology will have gained a thorough mechanistic understanding of the processes inducing radiation effects at different levels of biological organisation, including the consequences on ecosystem integrity, and be able to accurately predict effects under realistic conditions.

The respondents evaluated the importance and feasibility of research lines (i.e how difficult will it be to achieve them over the next 20 years) which are grouped below by the challenge that they address.

- Mechanistically understand how processes link radiation induced effects in wildlife from molecular to individual levels of biological complexity.
- Understand what causes intra- and inter-species differences in radiosensitivity (e.g. among cell types, tissues, life stages, life histories, ecological characteristics).
- Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants).
- Understand the mechanisms underlying multi-generational responses to long-term ecologically relevant exposures (e.g. maternal effects, hereditary effects, adaptive responses, genomic instability, and epigenetic processes).

- Understand how radiation effects combine in a broader ecological context at higher levels of biological organisation (population dynamics, trophic interactions, indirect effects at the community level, and consequences for ecosystem functioning).

Table 11: Means and standard deviations in answers related to radioecology - challenge 2- To Determine Ecological Consequences under Realistic Exposure Conditions

Challenge 2		Mean	Std.
Mechanistically understand how processes link radiation induced effects in wildlife from molecular to individual levels of biological complexity	Feasibility	48	22
	Importance	70	21
Understand what causes intra- and inter-species differences in radiosensitivity (e.g. among cell types_ tissues_ life stages_ life histories_ ecological characteristics)	Feasibility	52	21
	Importance	74	18
Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants)	Feasibility	51	21
	Importance	76	19
Understand the mechanisms underlying multi-generational responses to long-term ecologically relevant exposures (e.g. maternal effects_ hereditary effects_ adaptive responses_ genomic instability_ and epigenetic processes).	Feasibility	48.	25
	Importance	74	20
Understand how radiation effects combine in a broader ecological context at higher levels of biological organisation (population dynamics_ trophic interactions_ indirect effects at the community level_ and consequences for ecosystem functioning)	Feasibility	49	21
	Importance	74	20

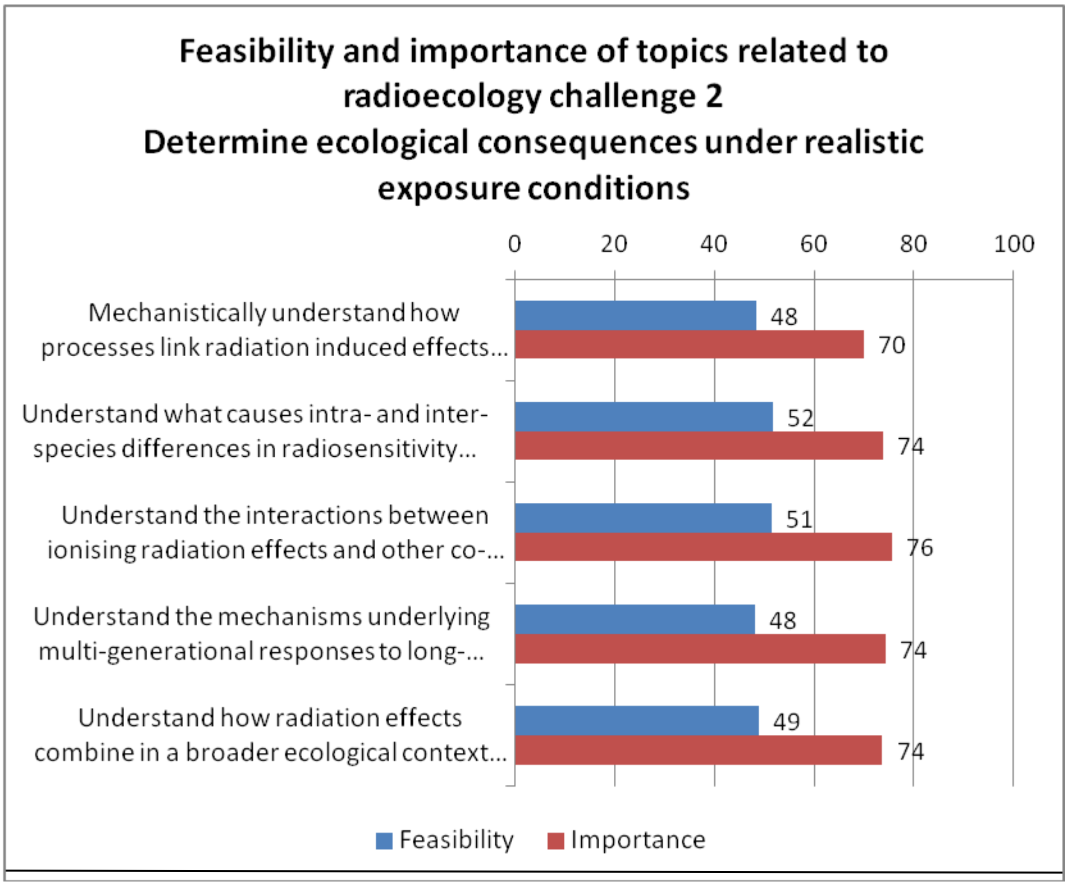


Figure 17: Feasibility and importance for topics related to radioecology, challenge 2 - Determine Ecological Consequences under Realistic Exposure Conditions

3.5.3 Radioecology Challenge 3: To Improve Human and Environmental Protection by Integrating Radioecology

Over the next 20 years radioecology will develop the scientific foundation for the holistic integration of human and environmental protection, as well as their associated management systems.

Respondents shared their view about the importance and feasibility (i.e how difficult will it be to achieve them over the next 20 years) of achieving each of these research lines which are grouped below by the challenge that they address.

- Integrate uncertainty and variability from transfer modelling, exposure assessment, and effects characterisation into risk characterisation.
- Integrate human and environmental protection frameworks.
- Integrate the risk assessment frameworks for ionising radiation and chemicals.
- Provide a multi-criteria perspective in support of optimised decision-making.
- Integrate ecosystem approaches, ecosystem services and ecological economics within radioecology.
- Integrate Decision Support Systems.

Table 12: Means and standard deviations in answers related to radioecology - challenge 3 - To Improve Human and Environmental Protection by Integrating Radioecology

Challenge 3		Mean	Std.
Integrate uncertainty and variability from transfer modelling_ exposure assessment_ and effects characterisation into risk characterisation	Feasibility	59	20
	Importance	74	19
Integrate human and environmental protection frameworks	Feasibility	62	21
	Importance	72	22
Integrate the risk assessment frameworks for ionising radiation and chemicals	Feasibility	59	21
	Importance	76	18
Provide a multi-criteria perspective in support of optimised decision-making	Feasibility	57	20
	Importance	71	22
Integrate ecosystem approaches_ ecosystem services and ecological economics within radioecology	Feasibility	52	23
	Importance	70	23
Integrate Decision Support Systems	Feasibility	58	20
	Importance	67	22

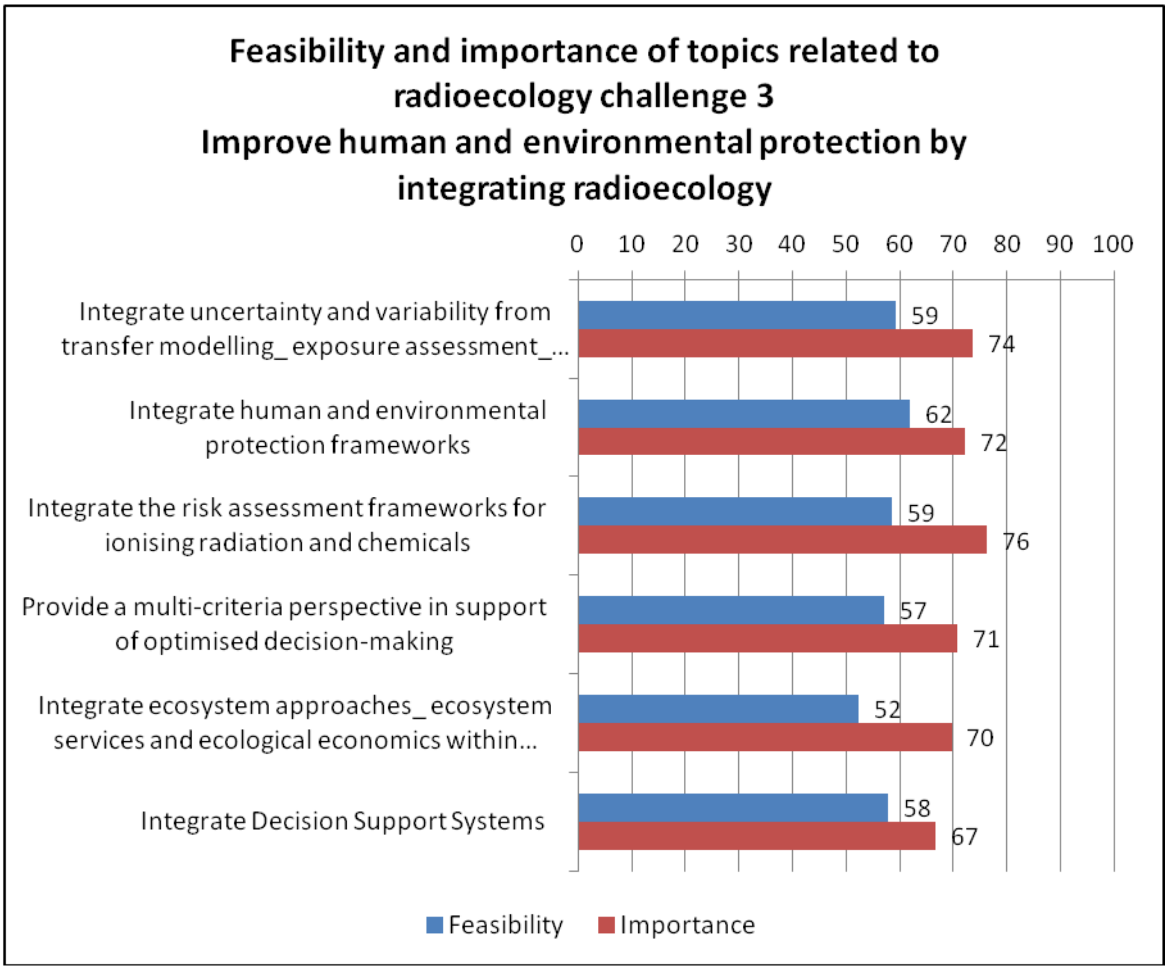


Figure 18: Feasibility and importance for topics related to radioecology, challenge 3 - To Improve Human and Environmental Protection by Integrating Radioecology

3.5.4 The three most important research lines from the radioecology

Respondents needed to select the research lines that they considered were the MOST important to address from the radioecology SRA. The following three lines were considered as the most important lines from the radioecology over the next 20 years:

1. Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife.
2. Acquire the data necessary for parameterization of the key processes controlling the transfer of radionuclides.
3. Develop transfer and exposure models that incorporate physical, chemical and biological interactions, and enable predictions to be made spatially and temporally.

These research lines are followed by the importance of the following topics:

4. Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants).
5. Understand what causes intra- and inter-species differences in radiosensitivity (e.g. among cell types, tissues, life stages, life histories, ecological characteristics).
6. Integrate human and environmental protection frameworks.
7. Integrate uncertainty and variability from transfer modelling_ exposure assessment_ and effects characterisation into risk characterization.
8. Understand the mechanisms underlying multi-generational responses to long-term ecologically relevant exposures (e.g. maternal effects, hereditary effects, adaptive responses, genomic instability, and epigenetic processes).
9. Understand how radiation effects combine in a broader ecological context at higher levels of biological organisation (population dynamics, trophic interactions, indirect effects at the community level, and consequences for ecosystem functioning).
10. Mechanistically understand how processes link radiation induced effects in wildlife from molecular to individual levels of biological complexity.
11. Integrate the risk assessment frameworks for ionising radiation and chemicals.
12. Represent radionuclide transfer and exposure at a landscape or global environmental level with an indication of the associated uncertainty.
13. Integrate Decision Support Systems.
14. Integrate ecosystem approaches, ecosystem services and ecological economics within radioecology.
15. Provide a multi-criteria perspective in support of optimised decision-making.

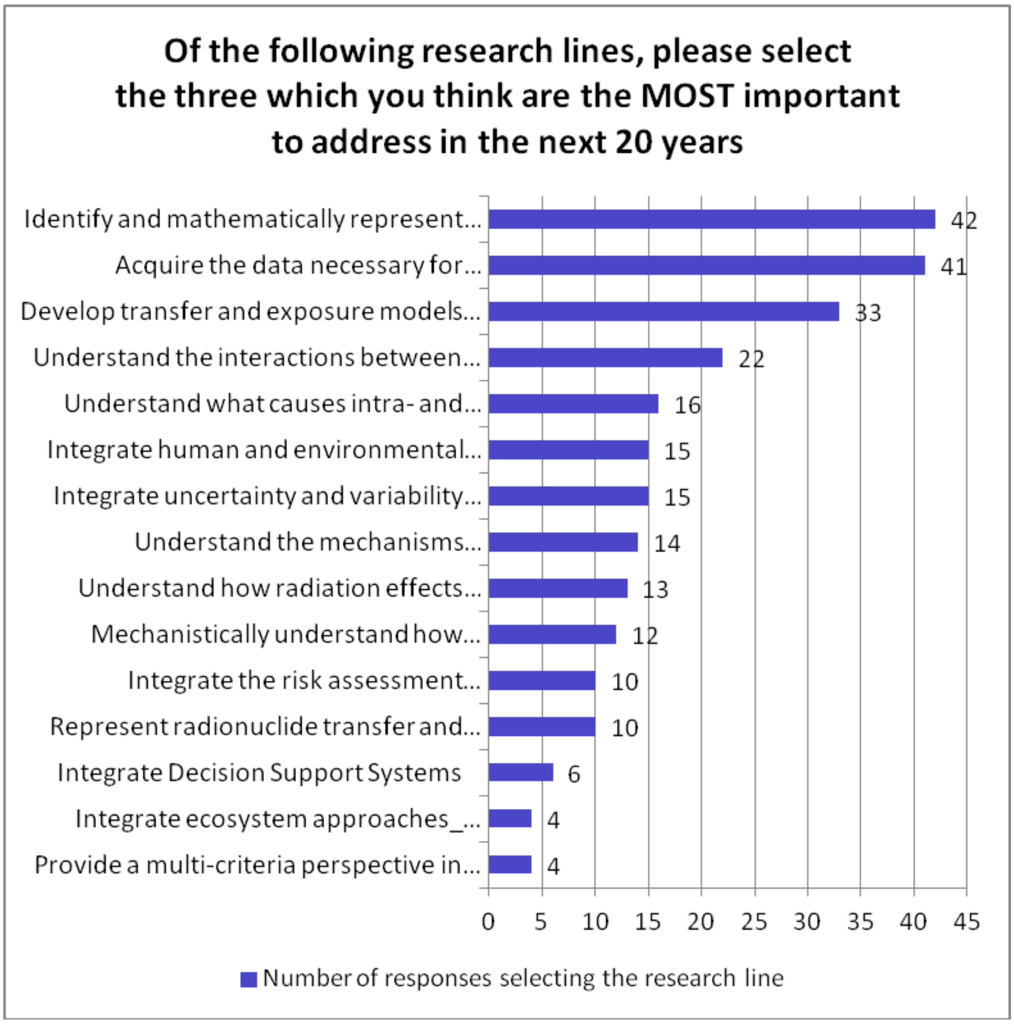


Figure 19: The research lines to be addressed by radioecology in the next 20 years

Respondents were asked to explain their decisions related to the three selected research lines. The table below includes all comments and selected topics. It also includes comments from respondents who started but did not submit the eSurvey, but none the less selected three topics and explained their decision.

Table 13: Motivation for the three selected research lines

The topics selected	**Explanation why they selected three MOST important research lines**
Integrate uncertainty and variability from transfer modelling exposure assessment and effects characterisation into risk characterization Integrate human and environmental protection frameworks Integrate the risk assessment frameworks for ionising radiation and chemicals	They will provide key information for improving the decision making process
Identify and mathematically represent key processes that make significant contributions to the environmental	They integrate complex information. producing results of the highest importance

transfers of radionuclides and resultant exposures of humans and wildlife Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Develop transfer and exposure models that incorporate physical chemical and biological interactions_ and enable predictions to be made spatially and temporally	
Mechanistically understand how processes link radiation induced effects in wildlife from molecular to individual levels of biological complexity Understand what causes intra- and inter-species differences in radiosensitivity e.g. among cell types_ tissues_ life stages_ life histories_ ecological characteristics Understand the interactions between ionising radiation effects and other co-stressors i.e. multiple contaminants	These research lines aim to elucidate the process of action of IR. Wildlife is a wonderful model that was not enough studied. Output of these researches will have a great impact for human radiation protection.
Integrate the risk assessment frameworks for ionising radiation and chemicals Understand how radiation effects combine in a broader ecological context at higher levels of biological organisation (population dynamics_ trophic interactions_ indirect effects at the community level_ and consequences for ecosystem functioning) Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants)	The environment is very complex and includes multiple interacting stressors. Unless we prioritize an approach integrating chemical and radiation exposure at the political. mechanistic and modelling level. we can't really hope to develop meaningful ways to protect the environment for human and non-human biota.
Integrate human and environmental protection frameworks Understand how radiation effects combine in a broader ecological context at higher levels of biological organisation (population dynamics_ trophic interactions_ indirect effects at the community level_ and consequences for ecosystem functioning) Mechanistically understand how processes link radiation induced effects in wildlife from molecular to individual levels of biological complexity	It is important to focus resources to try to understand why protection of the environment is important; otherwise it simply become a largely academic exercise. Therefore efforts should be spent to try to find out what the effects are if any at a macroscopic level (individual. populations). It is also important to integrate protection of the environment with protection of humans in order to refine if necessary current regulations.
Understand what causes intra- and inter-species differences in radiosensitivity (e.g. among cell types_ tissues_ life stages_ life histories_ ecological characteristics) Integrate human and environmental protection frameworks Integrate the risk assessment frameworks for ionising	1. Understanding differences in radio sensitivity provides added value towards understanding DNA repair in general. 2. Integrated assessment of humans and wildlife provides more unified protection goals that are easier to demonstrate compliance to. 3. Integrated assessments of chemicals and radioisotopes simplifies and unifies regulatory framework.

radiation and chemicals	
Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally	Human and more specifically wildlife exposure are currently not assessed in a robust way. These three lines will help to fill this gap.
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants)	They are basic issues and important for risk estimations.
Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally Understand what causes intra- and inter-species differences in radiosensitivity (e.g. among cell types_ tissues_ life stages_ life histories_ ecological characteristics) Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants)	Because for my point of view. based on work already done. it is now time to try and have an integrated and more processed-based view on how radionuclides are transferred along the biosphere. including environmental species and not only human beings. and how they affect organisms together with other contaminants .
Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally Integrate uncertainty and variability from transfer modelling_ exposure assessment_ and effects characterisation into risk characterization Integrate the risk assessment frameworks for ionising radiation and chemicals	Integrate the risk assessment frameworks for ionising radiation and chemicals' is important to broaden understanding and acceptance for radiation protection principles/priorities in an wider scientific community. 'Develop transfer and exposure models that incorporate physical. chemical and biological interactions. and enable predictions to be made spatially and temporally' because it integrates most of the traditional radio ecological work - which will have to be taken further. 'Integrate uncertainty and variability from transfer modelling. exposure assessment. and effects characterisation into risk characterization' because it represents a pathway from traditional radioecology with the wider risk assessment community.
Identify and mathematically represent key processes that make significant contributions to the environmental	These provide the first basis for modelling the behaviour of RN in the environment.

transfers of radionuclides and resultant exposures of humans and wildlife Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally	The work on latter questions might be using these data as starting point.
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Represent radionuclide transfer and exposure at a landscape or global environmental level with an indication of the associated uncertainty Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants)	Still the basis for the assessment of transfer processes is not solid enough. The detailed knowledge of transfer processes in the environment can improve the prediction and the planning of countermeasures considerably. The research priorities dealing with decision support systems and integration of systems can come on top.
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Mechanistically understand how processes link radiation induced effects in wildlife from molecular to individual levels of biological complexity Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants)	I think that firstly it is more important to know and understand the mechanisms of molecular and cellular responses to radiation and also the effect at higher levels of organization and also how transfers occur.
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally	There is significant uncertainty in these areas and there is a sufficient scientific knowledge at present to reduce this uncertainty. provided research funding is directed to these items. In short. they are achievable goals that would result in a quantum advancement in the field.
Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants) Integrate uncertainty and variability from transfer modelling_ exposure assessment_ and effects	The three selected items will lead to a better understanding of risks arising from radiation and/or other hazards also in comparison. Radiation is mostly understood by the public associated with the highest risk due to disinformation. It is important to put the different risks into relative perspective.

characterisation into risk characterization	
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally	Because they are the most important.
Understand the mechanisms underlying multi-generational responses to long-term ecologically relevant exposures (e.g. maternal effects_ hereditary effects_ adaptive responses_ genomic instability_ and epigenetic processes) Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Provide a multi-criteria perspective in support of optimised decision-making	Before we continue to (micro)model we need to understand the underlying parameters governing environmental behaviour. We partially do understand those however for a limited number of radionuclides. For remediation purposes and preparedness it is important to then integrate this knowledge into multi criteria decision support systems.
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally Understand how radiation effects combine in a broader ecological context at higher levels of biological organisation (population dynamics_ trophic interactions_ indirect effects at the community level_ and consequences for ecosystem functioning)	Most important to the type of work that I do.
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants) Integrate uncertainty and variability from transfer modelling_ exposure assessment_ and effects characterisation into risk characterization.	These represent the need for greater understanding and modelling of risks.
Understand how radiation effects combine in a broader ecological context at higher levels of biological organisation (population dynamics_ trophic interactions_ indirect effects at the community level_	Would deliver what is most lacking at this present stage. with reference also to support for decision-making processes.

and consequences for ecosystem functioning) Integrate human and environmental protection frameworks Integrate the risk assessment frameworks for ionising radiation and chemicals	
Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants) Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides	Are basic research lines essential for the development of others?
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Understand what causes intra- and inter-species differences in radiosensitivity (e.g. among cell types_ tissues_ life stages_ life histories_ ecological characteristics) Integrate the risk assessment frameworks for ionising radiation and chemicals	I think the three subjects are the ones that the public either would be most interested to know. or lack in knowledge. Also, the research results would put the risk of radiation in a more proper perspective with regard to other sources that pose risks to the human and/or environmental health.
Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants) Integrate ecosystem approaches_ ecosystem services and ecological economics within radioecology	Lack of current knowledge
Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally Integrate uncertainty and variability from transfer modelling_ exposure assessment_ and effects characterisation into risk characterization Integrate the risk assessment frameworks for ionising radiation and chemicals	Some of the topic are not concise formulated. i.e. manily containing general keywords without providing any clear picture what will be achieved (e.g topic 1. 2). For me that means that either the proposal has no clear picture of what should be done or the proposer tries to keep fully flexibility to do what the want. Thus these alternatives fail of to be feasible to really solve an important subject. Some other topics are important but the describing text gives the impression that the

	topic is captured in one paradigm which will never make it feasible to achieve the goal (e.g topic 5). Some topics are rather an short implementation of the results. e.g. the last topic. An integrated decision support system is something you do not spend 20 strategic years on, you just do it now and that must be paid by other funds not research funds. From the leftovers there are several important and more and less feasible topics. From my viewpoint it is essential both from the development and maintenance of radioecology to incorporate physical and chemical and biological interactions. This is also necessary for the safety assessments to have an process understanding to make creditable predictions/scenarios of the future conditions. From that viewpoint it is important to improve modelling for risk estimates, even if that partially is applying the knowledge from a strategic programme. currently fundamental understanding of process interactions are missing from most models today, which essentially are derived from the beginning of 80ies. It absolutely important to have a mutual understanding of chemical and environmental risks for the environment. In that sense radioecology needs to build more bridges with ecotoxicology which already has some decades of understanding how the environment is affected by stressors.
Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants) Understand the mechanisms underlying multi-generational responses to long-term ecologically relevant exposures (e.g. maternal effects_ hereditary effects_ adaptive responses_ genomic instability_ and epigenetic processes) Understand how radiation effects combine in a broader ecological context at higher levels of biological organisation (population dynamics_ trophic interactions_ indirect effects at the community level_ and consequences for ecosystem functioning)	To develop and improve human medicine. We need a shift in paradigm. The complexity of interaction between humans. Societies and nature creates a need for new treatment strategies in disease as well as in health and growth.
Represent radionuclide transfer and exposure at a landscape or global environmental level with an indication of the associated uncertainty Mechanistically understand how processes link radiation induced effects in wildlife from molecular to individual levels of biological complexity	They will help in gaining the basic fundamental knowledge to build upon in order to develop a credible. Robust and consistent operational approach for low dose risk in human and non-human species.

Understand the mechanisms underlying multi-generational responses to long-term ecologically relevant exposures (e.g. maternal effects_ hereditary effects_ adaptive responses_ genomic instability_ and epigenetic processes)	
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally Integrate uncertainty and variability from transfer modelling_ exposure assessment_ and effects characterisation into risk characterization	The key processes for environmental transfer of radionuclides are not clearly defined. The uncertainty of model prediction is high due to the absence of continuous data in a temporal and spatial base.
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Understand what causes intra- and inter-species differences in radiosensitivity (e.g. among cell types_ tissues_ life stages_ life histories_ ecological characteristics)	Because of the lack of adequate scientific knowledge of the 3 research lines. which are the key-lines for the successful implementation of all the others
Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants) Understand how radiation effects combine in a broader ecological context at higher levels of biological organisation (population dynamics_ trophic interactions_ indirect effects at the community level_ and consequences for ecosystem functioning) Integrate uncertainty and variability from transfer modelling_ exposure assessment_ and effects characterisation into risk characterization	They will contribute the greatest is they are able to be done.
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally.	These data and tools are now achievable and would give very useful information for stakeholders for radioecology or stable pollutants

Integrate uncertainty and variability from transfer modelling_ exposure assessment_ and effects characterisation into risk characterization. Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally	Areas where there seems to be a lot of uncertainties but could be 'easily' fixed
Integrate uncertainty and variability from transfer modelling_ exposure assessment_ and effects characterisation into risk characterization Integrate ecosystem approaches_ ecosystem services and ecological economics within radioecology Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides	Transfer knowledge is the basis of radioprotection (where. when. how much) Convenient modelling of these processes requires data (considering that key transfer mechanisms are globally known) and associated uncertainty needs to be modelled to assess risks Final use of transfer models is to provide decision support to territories managers (political level) and should be inserted in DSS tools
Represent radionuclide transfer and exposure at a landscape or global environmental level with an indication of the associated uncertainty Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides	These three main research lines allow us to keep our commitment to foster interdisciplinary synergy.
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Mechanistically understand how processes link radiation induced effects in wildlife from molecular to individual levels of biological complexity	We think it is very important to understand the underlying mechanisms and to consider them in the modelling.
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Mechanistically understand how processes link radiation induced effects in wildlife from molecular to individual levels of biological complexity	Because I think that an understanding on the interactions of radionuclides with biological systems (i.e. the mechanisms) is a prerequisite for the development of newer and better models.

Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants) Understand how radiation effects combine in a broader ecological context at higher levels of biological organisation (population dynamics_ trophic interactions_ indirect effects at the community level_ and consequences for ecosystem functioning) Integrate ecosystem approaches_ ecosystem services and ecological economics within radioecology	They are most prone to allow linking scientific knowledge to the ecological impact realism necessary to inform ecological risk assessment of radiation
Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally Understand the mechanisms underlying multi-generational responses to long-term ecologically relevant exposures (e.g. maternal effects_ hereditary effects_ adaptive responses_ genomic instability_ and epigenetic processes)	1 choice: extrapolation methods introduce large uncertainties. moreover difficult to quantify => there is a need for real data! include for me the identification of key processes. in order to acquire corresponding data 2 choice: logical next step after first choice 3 choice: data acquisition could be relatively easily at the level of individuals. but much more complicated for higher levels of organisation that are the one of interest for protecting the environment=> approaches/method are required to go "from the lab to the real world"
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally	Understanding basic processes and being able to parameterize and use models is the only reliable way for extrapolations of filed and lab data to the wide variety of species 7 conditions found in real life.
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Integrate human and environmental protection frameworks Integrate the risk assessment frameworks for ionising radiation and chemicals	Focus on policy in real problem situations
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides	Because identification and characterization of risk to the human population is of the greatest importance

Integrate uncertainty and variability from transfer modelling_ exposure assessment_ and effects characterisation into risk characterization	
Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants) Understand how radiation effects combine in a broader ecological context at higher levels of biological organisation (population dynamics_ trophic interactions_ indirect effects at the community level_ and consequences for ecosystem functioning) Integrate human and environmental protection frameworks	Important to integrate radioprotection applied to ecology at the large sense. Important to understand the effects of radiation on the environment.
Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Integrate human and environmental protection frameworks Integrate the risk assessment frameworks for ionising radiation and chemicals	Integration of human and environmental approaches to radiation protection is not yet fully understand and therefore. it makes some confusion . esp. in explaining the risk from ionising radiation to population.
Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally Understand how radiation effects combine in a broader ecological context at higher levels of biological organisation (population dynamics_ trophic interactions_ indirect effects at the community level_ and consequences for ecosystem functioning) Integrate Decision Support Systems	The progress in knowledge and development of the three research lines selected will strongly contribute to a better prediction of the final consequences of ionising radiation in living organisms (both human and non-human).
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Integrate uncertainty and variability from transfer modelling_ exposure assessment_ and effects characterisation into risk characterization	The role of radioecology in European Radiation Protection and in the perception by the public will be most pronounced if it can identify the key processes and pathways that lead to significant human exposures at least in the several mSv ranges. Mathematical models should always be controlled and backed up by experimental data. Finally uncertainty is the key information for risk assessment.
Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally Mechanistically understand how processes link radiation induced effects in wildlife from molecular to individual levels of biological complexity	Develop transfer and exposure models that incorporate physical. Chemical and biological interactions. and enable predictions to be made spatially and temporally ..... is the end product of the RL above. Effects related - important and high profile

Understand how radiation effects combine in a broader ecological context at higher levels of biological organisation (population dynamics_ trophic interactions_ indirect effects at the community level_ and consequences for ecosystem functioning)	questions
Develop transfer and exposure models that incorporate physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally Integrate human and environmental protection frameworks	The main challenge for Radioecology research is to provide knowledge that will (1) significantly enhance the robustness ecological risk assessment of ionising radiation to non-human biota (i.e. protective enough). (2) Allow a quantitative quantification of risk levels compared to other stress for the ecosystems and human populations. First. The identification (and description/quantification) of adapted mechanistic refinements of transfer and exposure models is needed (funded on sound physical. chemical and biological processes) for a better description of spatial heterogeneity and temporal dynamics of exposures (post-accidental exposures. long term contamination). Similarly. Challenge 2 objectives needs to provide a comprehensive understanding of biological effects of ionizing radiation on ecologically-relevant species and endpoints (i.e. linked to the preservation of ecosystems structure and functions that rely also to multi-generational effects. species sensitivity and inter-species effects). Those knowledge improvements will need to be linked with a broader objective: the integration of human and environmental protection frameworks in order to quantify. in a robust way. the risk to ecosystems. its comparison to human populations exposure and to other stress factors (e.g. stable chemicals exposures).
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Integrate uncertainty and variability from transfer modelling_ exposure assessment_ and effects characterisation into risk characterization	To study radioecology transfer we need conceptual and mathematical models to simulate. Parameterization to calibrate biological half-lives and uncertainty evaluation to assess risks.
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Develop transfer and exposure models that incorporate	First of all it is necessary to understand properly the behaviour of the radionuclides transfer and transportation in the environment before entering to evaluate their effects on biological species. Step by step.

physical_ chemical and biological interactions_ and enable predictions to be made spatially and temporally	
Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides Integrate human and environmental protection frameworks	Acquisition of sufficient representative data and a fundamental understanding of its meaning should enable integration with well-developed human rp frameworks enabling the development of a robust total radioprotection approach.

Respondents were requested to indicate for their three MOST important research lines, which situation(s) should receive priority.

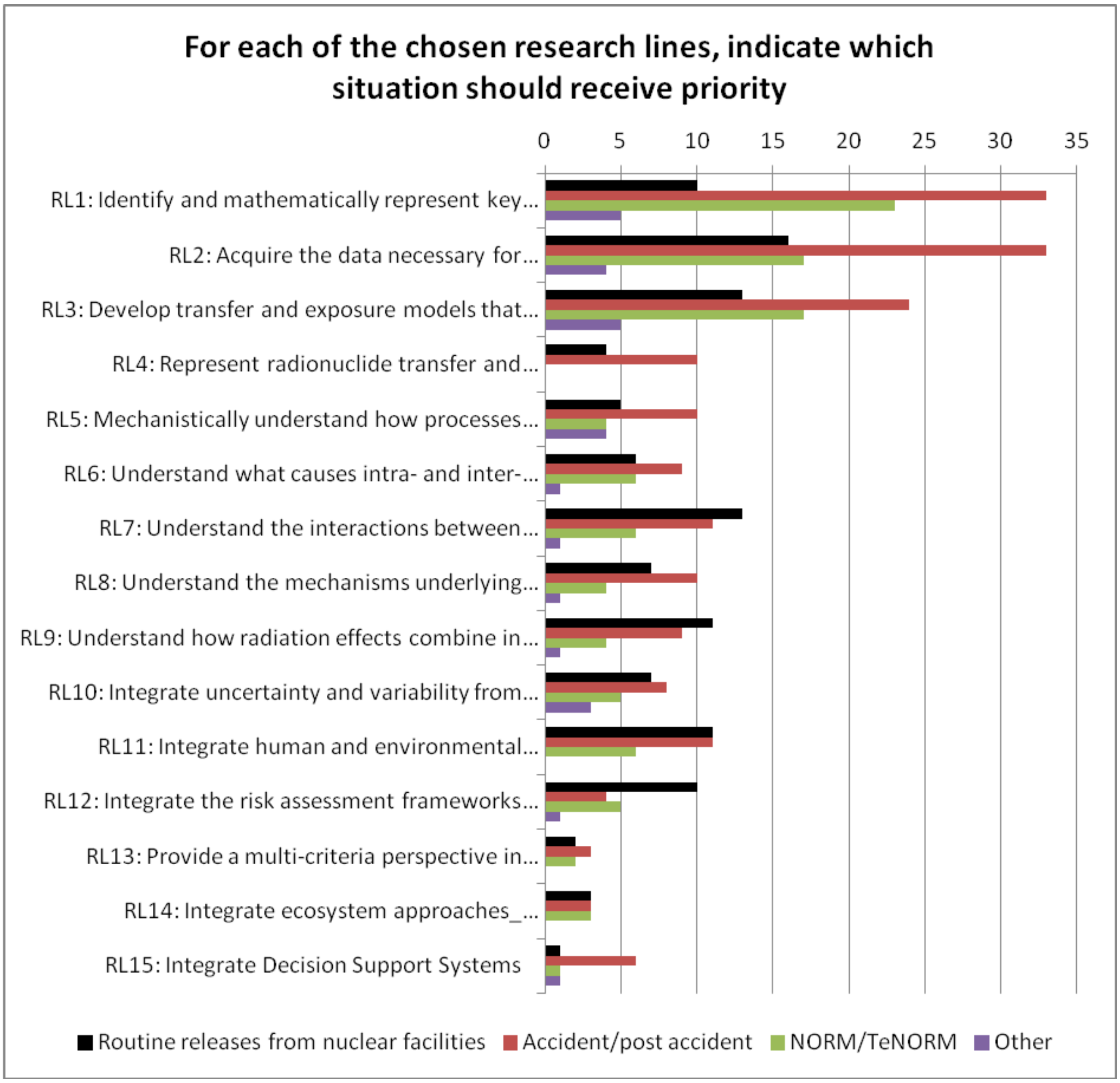


Figure 20: Situations to be given priority for the three most important three research lines

Table 14: Additional issues related to individual and general health and radiation protection suggested by respondents

	Alliance
	Are there important research lines which you consider are missing from the SRA? Please explain why you think they should be included.
	Comments: 8
1	Maintain attention for experiments
2	No. There are too many of them in the SRA. SRA should be more focused and not listing all what you can remember about. This is actually no strategy at all if you have everything what you can remember in it.
3	Not really. However the research line are kept very theoretical and "big picture" like - potentially needed for such surveys - and do not provide details eg radionuclides. Deposition scenarios etc. All of those will influence environmental behaviour and relevant remediation activities.

4	Releases of radionulides from hospitals treating patients with high levels of beta/gamma radionuclides (e.g. Tc-99m. I-131) and alphas (e.g. Ra-223) contribute significantly to the ecological burden and further research into the mechanisms of transfer (e.g. sludge to farming communities. fishing etc.).
5	First of all in the options given an extremely important topic is missing. a large part of work considering facilities are safety assessment. that is no release nor accident and sometimes very long timescales which requires other understanding than that acquired from accidental releases. Moreover these releases are from point sources and the dispersal and transport of the radionuclides is as important as the properties of the radionuclides themselves. Thus I am lacking clear connections to hydrology. meteorology. oceanography and "normal" ecology as dispersal agent. To be able to make any sensible predictions these disciplines need to more integrated in radioecology.
6	State of art methods for characterizing sites due to radioactivity fallout are of high importance.
7	You need to quantify the adverse effect on the biota once the dose to biota has been determined.
8	Integrate ecological knowledge and processes in the chain from exposure to effect in order to support more integrated methods for ecological risk assessment better aligned with current management goals

Table 15: Additional comments and suggestions for the ALLIANCE SRA

	ALLIANCE
	We welcome any additional comments and suggestions
	Comments: 5
1	To promote communication and encourage joint working between all parties
2	I think that much importance is given to nuclear power plants and nuclear accidents while uranium mines are apparently forgotten. I think it would be good to re-think this. Because there are much more uranium mines (active and abandoned) than nuclear power plants and nuclear accidents and their contribution to environmental contamination is also high in many countries around the world. Namely in underdeveloped countries that do not have legislation to protect the environment and human populations. Moreover. The problematic of abandoned uranium mines and high environmental contamination. In many European countries is still a reality nowadays.
	I would suggest that you finally start spending the money on the research. Those strategic/alliance/integration/etc. seems like never-ending story of burning the money. Much needed for the research. In the furnace in order that we all feel warm and that it looks like that we are doing something.
3	Emphasis to "One health concept" with the eco-centric approach on equal footing with the anthropo-centric one
4	The structure of a radiation protection platform established from assembling Melodi. Alliance. Eurados and Neris is not optimized and well balanced with respect to their respective scientific focus. This would probably need revision in the future along a better conceptualized rationale.
5	I think we should pay special attention to the study of ecosystems and the development of integrated parameters (not a single biomarker) characterizing the reaction of whole cenosis on radiotoxic effects.

The content of all radioecology strategic agenda free texts is reported and summarized in annex 1 (pp 94)

3.6 EMERGENCY AND RECOVERY PREPAREDNESS

The European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery (NERIS Platform) was launched in June 15, 2010. Research and development in the field of emergency management and recovery at the European level calls for co-operation among authorities, emergency centres, research organisations and the academic community in different countries, as well as interactions with key concerned stakeholders. The NERIS Strategic Research Agenda (SRA) contains broader areas where further research and development are needed. Seven Key Topics are identified and grouped in three research areas as follows:

1. New challenges in atmospheric & aquatic modelling – Needs for improvement.
2. New challenges for better dose assessments and decision support based on improved knowledge: source term, scenarios, etc.

3. New challenges in stakeholder involvement and local preparedness and communication strategies.

3.6.1 NERIS Research Area 1, Key Topic 1: New challenges in atmospheric dispersion modelling

Atmospheric dispersion modelling - Needs for improvement aims at making more reliable and precise forecasts on atmospheric dispersion of radioactive materials in different environments. This will extend the capabilities of Decision Support Systems and will provide decision makers and other actors with a more reliable picture of the situation.

Respondents were requested to indicate the importance/feasibility of the topics related to Atmospheric dispersion modelling on the scale Feasibility: High-Low; Importance: High-Low for the following topics:

- Modelling approaches for complex settings (e.g. urban, confined spaces).
- Data assimilation (e.g. dose rates and concentrations) and inverse modelling.
- Dispersion models for non-conventional emissions (e.g. explosions, two-phase, aerosol sprays, fires, etc.) of particular substances (e.g. aerosol, phase-changing, multi-sized particles, etc.).
- Fine tuning modelling parameters & algorithms (to treat specific phenomena such as wet deposition by snow).
- Optimised use of new meteorological instruments (esp. mobile measurement units).
- Simulation of (very) long-duration releases (>1 month) to air.

Table 16: Means and standard deviations in answers related to NERIS Research area 1, Key topic 1- Atmospheric dispersion modelling

NERIS Research area 1, Atmospheric dispersion modelling		**Mean**	**Std.**
Modelling approaches for complex settings (e.g. urban_ confined spaces).	Feasibility	57	19
	Importance	70	19
Data assimilation (e.g. dose rates and concentrations) and inverse modelling	Feasibility	62	17
	Importance	68	18
Dispersion models for non-conventional emissions (e.g. explosions_ two-phase_ aerosol sprays_ fires_ etc.) of particular substances (e.g. aerosol_ phase-changing_ multi-sized particles_ etc.)	Feasibility	57	22
	Importance	69	20
Fine tuning modelling parameters & algorithms (to treat specific phenomena such as wet deposition by snow)	Feasibility	60	20
	Importance	61	21
Optimised use of new meteorological instruments (esp. mobile measurement units)	Feasibility	72	19
	Importance	69	19
Simulation of (very) long-duration releases (>1 month) to air	Feasibility	62	20
	Importance	66	21

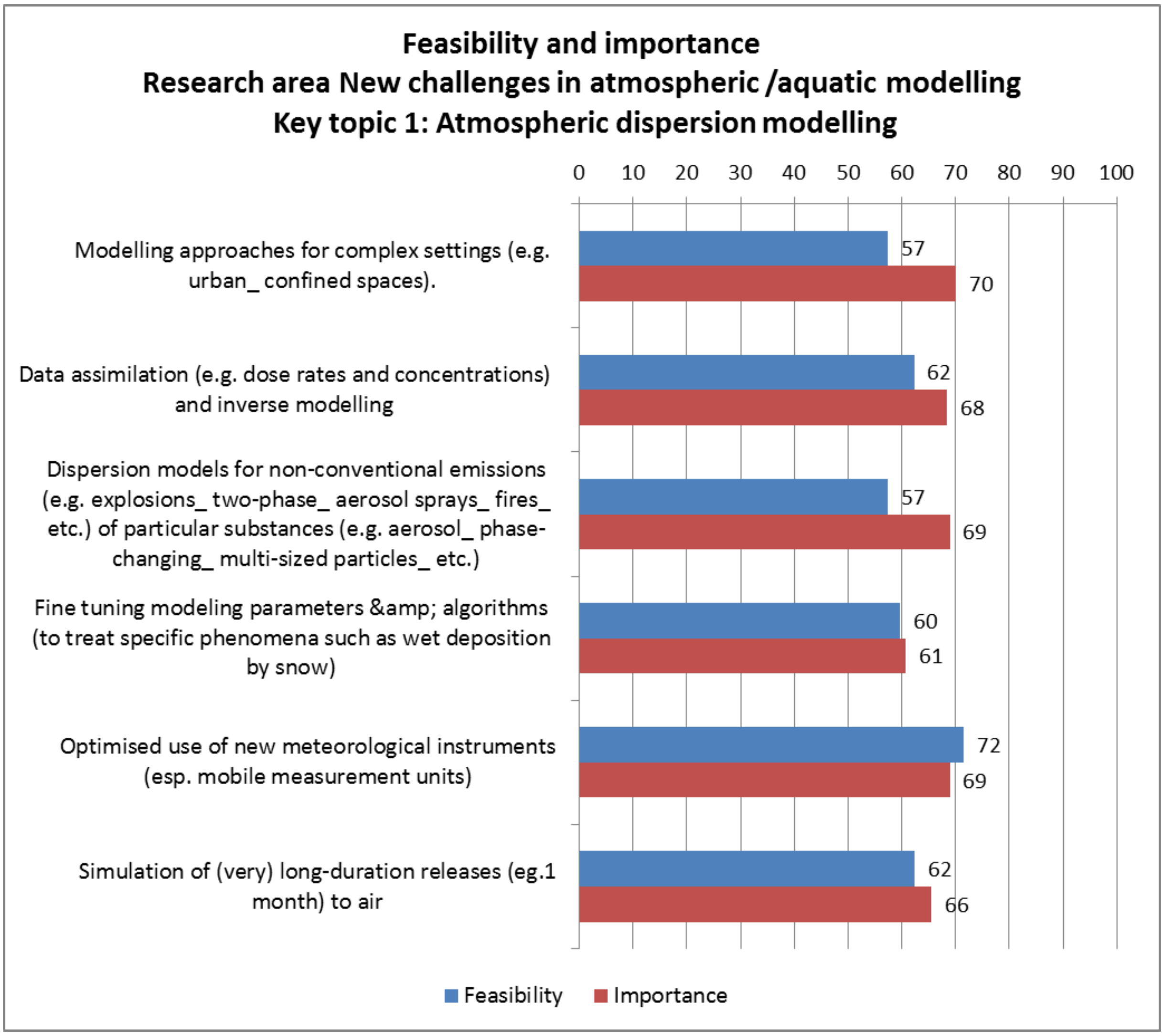


Figure 21: Feasibility and importance for topics related to NERIS Research area 1, Key topic 1- New challenges in atmospheric dispersion modelling

Table 17: Additional issues related to atmospheric dispersion modelling suggested by respondents

	Research area 1: New challenges in atmospheric & aquatic modelling – Needs for improvement **Key Topic 1: Atmospheric dispersion modelling - Needs for improvement aims at making more reliable and precise forecasts on atmospheric dispersion of radioactive materials in different environments.**
	Are there any additional issues related to atmospheric dispersion modelling issues you would like to suggest as a priority? Please specify.
	Comments: 7
1	Development of near-range models.
2	Developing common platform for long range atmospheric dispersion models which are user friendly. Fast and accurate .Validation of long range atmospheric transport models .
3	Need dispersion modeling for aquatic and other environments around NPP's.
4	Intermitent releases (1 weeks per month for example).
5	Decent in-house modelling capabilities are getting out of reach for smaller users due to the size of the datasets that have to be handled by the models (in particular met data). Processing time and storage/archiving are becoming an issue. Remote access to centralised modelling system should be encouraged (ECMWF. Hysplit community. Etc.).
6	Reliable measurement of potential atmospheric radioactive contamination.
7	Multiple release points.

3.6.2 NERIS Research Area 1- Key Topic 2: Aquatic dispersion modelling

Aquatic dispersion modelling aims at improving forecasts on aquatic dispersion of radioactive materials in different environments (urban hydrology systems and coastal waters). This will extend the capabilities of Decision Support Systems and will provide decision makers and other actors with a more reliable picture of the situation by allowing to assess:

- The vulnerability of urban hydrology systems to nuclear emergencies regarding the freshwater supply system and waste- water contamination from deposited radionuclides.
- The dispersion of radioactivity in coastal waters and radioactivity levels in fish and seafood.

Respondents were requested to indicate the importance/feasibility of the topics related to Aquatic dispersion modelling on the following scale: Feasibility: High-Low; Importance: High-Low. The following five topics were evaluated.

- Models for urban hydrology (contamination of urban fresh water supply & waste water from urban decontamination).
- 3D models for coastal areas (including long duration releases).
- Coupling with weather forecast models for running in the automatic mode of a Decision Support Systems and with sediment transport models.
- Runoff (land to sea) models.
- Development of finite volume models (e.g. for prolonged emergency phase modelling).

Table 18: Means and standard deviations in answers for topics related to NERIS Research area 1, Key topic 2- Aquatic dispersion modelling

NERIS Research area 1, Aquatic dispersion modelling		Mean	Std.
Models for urban hydrology (contamination of urban fresh water supply & waste water from urban decontamination)	Feasibility	63	18
	Importance	73	18
3D models for coastal areas (including long duration releases)	Feasibility	57	17
	Importance	66	20
Coupling with weather forecast models for running in the automatic mode of a Decision Support Systems and with sediment transport models	Feasibility	54	21
	Importance	63	19
Runoff (land to sea) models	Feasibility	58	19
	Importance	59	20
Development of finite volume models (e.g. for prolonged emergency phase modelling)	Feasibility	55	19
	Importance	59	20

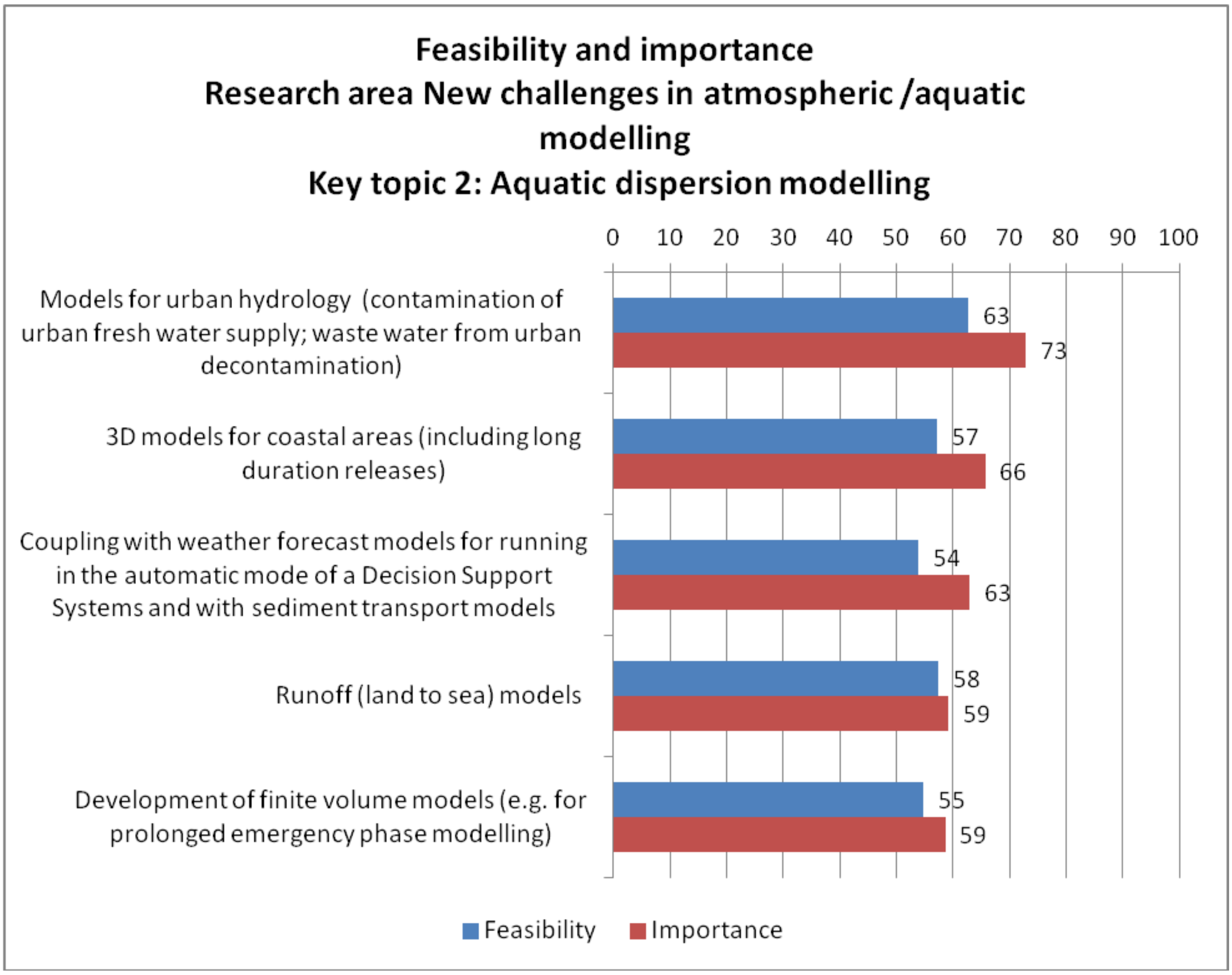


Figure 22: Feasibility and importance for topics related to NERIS Research area 1, Key topic 2-Aquatic dispersion modelling

Table 19: Additional issues related to aquatic dispersion modelling suggested by respondents

	Research area 1: New challenges in atmospheric & aquatic modelling – Needs for improvement **Key Topic 2: Aquatic dispersion modelling aims at improving forecasts on aquatic dispersion of radioactive materials in different environments (urban hydrology systems and coastal waters).**
	Are there any additional issues related to aquatic dispersion modelling issues you would like to suggest as a priority? Please specify.
	No. of comments: 3
1	Modelling and validation of concentration profiles during post release phase for a duration of months/years in case of large costal NPP facilities.
2	Intermittent releases. Torential mode (for river)
3	Technology for water purification and its influence on drinking water quality after contamination with radionuclides

3.6.3 NERIS Research Area 2 - Key Topic 3: Source term, scenarios, etc

Improvement of existing Decision Support Systems aims at obtaining a better analysis of the radiological situation (source-term, scenarios, etc.), and at supporting the decision-making processes at all (emergency and recovery) phases after an event. Expected results are:

- a better source-term input within dispersion models;
- an improvement of radio-ecological modelling;
- a better customization of Decision Support Systems according to local information;
- a better response to malevolent acts;
- a better analysis and response in the different exposure situations.

Respondents were asked to indicate the importance/feasibility of the topics related to Improvement of existing Decision Support Systems on the scale for Feasibility: High-Low; and importance: High-Low, for the following topics:

- Better quantification of source terms (according specific type of accidents and physico-chemistry of released substances).
- Customising of the existing environmental models into the regional circumstances in Europe.
- Measurements of Chernobyl and, if possible, Fukushima contaminants on different surfaces.
- Development of local radio-ecological models.
- Improvement of existing DSS for radiological emergencies (e.g. explosions in large buildings, underground events, uncertain source-term information, hidden sources, etc.).
- Tackle multiple stressors (e.g. CBRNE) in the assessment of countermeasure strategies.
- Tailor the output of DSS's to the users' needs.
- Development of rapid analytical tools with mobile and automated equipment.

Table 20: Means and standard deviations in answers for topics related to NERIS Research area 2, Key topic 3- Improvement of existing DSS

NERIS Research area 2, Improvement of existing DSS		**Mean**	**Std.**
Better quantification of source terms (according specific type of accidents and physico-chemistry of released substance)	Feasibility	65	16
	Importance	76	18
Customising of the existing environmental models into the regional circumstances in Europe (X)	Feasibility	66	19
	Importance	71	19
Measurements of Chernobyl and_ if possible_ Fukushima contaminants on different surfaces	Feasibility	72	19
	Importance	63	22
Development of local radio-ecological models	Feasibility	65	19
	Importance	63	22
Improvement of existing DSS for radiological emergencies (e.g. explosions in large buildings_ underground events_ uncertain source-term information_ hidden sources_ etc.)	Feasibility	66	19
	Importance	73	19
Tackle multiple stressors (e.g. CBRNE) in the assessment of countermeasure strategies	Feasibility	55	21
	Importance	63	21
Tailor the output of DSS's to the user's needs	Feasibility	66	20
	Importance	69	18
Development of rapid analytical tools with mobile and automated equipments	Feasibility	72	18
	Importance	77	14

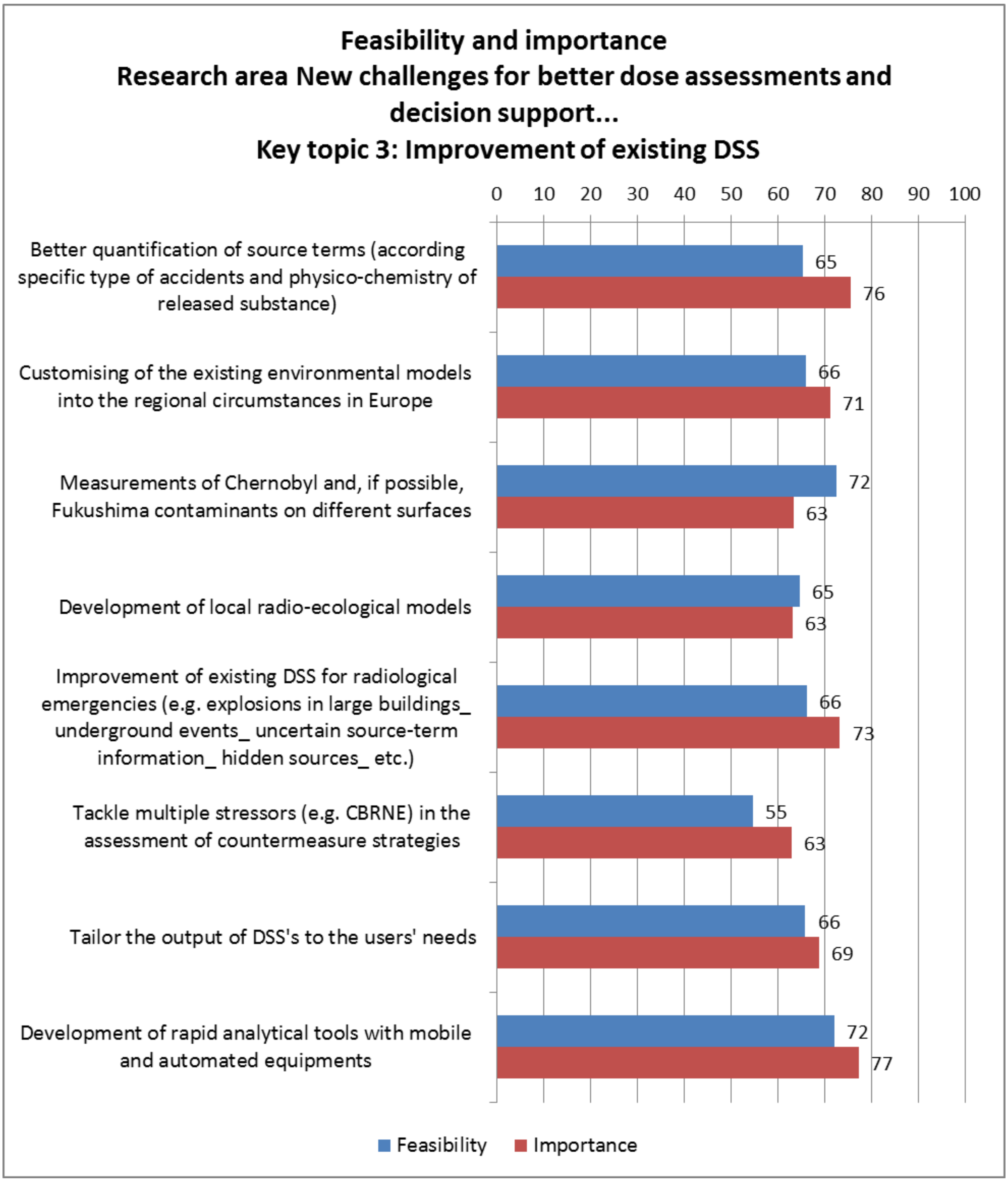


Figure 23: Feasibility and importance for topics related to NERIS Research area 2, Key topic 3-Improvement of existing DSS

Table 21: Additional issues related to improvement of existing DSS suggested by respondents

	Research area 2: New challenges for better dose assessments and decision support based on improved knowledge: source term, scenarios, etc **Key topic 3 Improvement of existing Decision Support Systems aims at obtaining a better analysis of the radiological situation (source-term, scenarios, etc.), and at supporting the decision-making processes at all (emergency and recovery) phases after an event.**
	Are there any additional issues related to improving existing Decision Support Systems you would like to suggest as a priority? Please specify.
	No of comments: 3
1	Android based DSS with GIS facility and integrated radiological dose projections and realtime measurement data update options.
2	Interpretation of vast numbers of monitoring results taking into account a multiplicity of endpoints and differences in timing
3	Implementing in the DSS procedures or systematic methodologies to select the most feasible countermeasure strategies for the regional or local characteristics.

3.6.4 NERIS Research Area 2 - Key Topic 4, Data mining, information gathering and providing information to stakeholders and mass media

Data mining, information gathering and providing information to stakeholders and mass media aims at fostering the information exchange between all interested stakeholders, and at providing means for a more transparent decision-making process. Expected results are:

- To develop an information exchange platform for all relevant organisations in Europe.
- To allow decision-makers to learn lessons from historic events.

Respondents were asked to indicate the importance/feasibility of the topics related to Data mining, information gathering and providing information to stakeholders and mass media using the scale Feasibility: High-Low; Importance: High-Low:

- Establishment of a Europe-wide analytical platform for operational data and information exchange.
- Development of a knowledge database (‘lessons to be learned from historic events’).
- Understanding of what could make the information trustworthy and more effective (e.g. development and usage of social media in emergency response; communication-cooperation with the public).
-

Table 22: Means and standard deviations in answers for topics related to NERIS Research area 3, Key topic 4 - Data mining information gathering and providing information to stakeholders and mass media

NERIS Research area 3, Data mining information gathering and providing information to stakeholders and mass media		**Mean**	**Std.**
Establishment of a Europe-wide analytical platform for operational data and information exchange	Feasibility	63	25
	Importance	78	19
Development of a knowledge database (‘lessons to be learned from historic events’)	Feasibility	78	16
	Importance	78	18
Understanding of what could make the information trustworthy and more effective (e.g. development and usage of social media in emergency response; communication-cooperation with the public)	Feasibility	64	21
	Importance	79	20

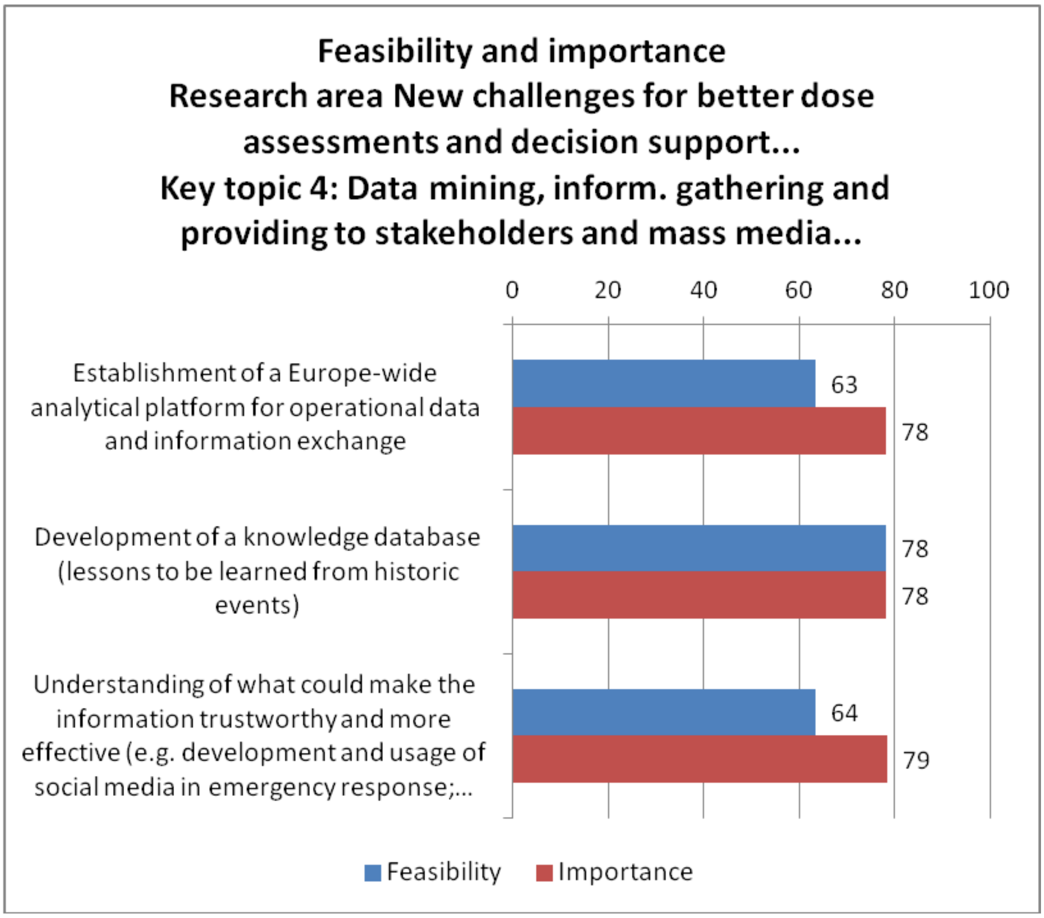


Figure 24: Feasibility and importance for topics related to NERIS Research area 3, Key topic 4 - Data mining, information gathering and providing information to stakeholders and mass media

3.6.5 NERIS Research Area 2 - Key Topic 5: Improving of the decision-making processes

Improving of the decision-making processes aims at improving decision processes. Expected results are:

- better structured decision processes at national, regional and local levels involving the different categories of stakeholders (public authorities, professionals, inhabitants);
- a more accurate information to the emergency and recovery stakeholders;
- a more efficient use of existing Decision Support Systems and tools;
- a better allocation of resources and improvement of the efficiency of protective strategies during emergency and recovery phases.

Respondents were requested to indicate the importance/feasibility of the topics related to Improving of the decision-making processes:

- assessment of and communication on uncertainties;
- coupling of Decision Support Systems with Command and Control systems;
- improvement of decision-making processes through the development of guidances and multi-criteria analysis decision-aiding tools, taking into account the feedback from stakeholder processes (e.g. from Fukushima);
- development of serious gaming (for stakeholder education and training);
- revision of European handbooks considering malevolent acts;
- development of tools for the usage at the local level, which are compatible with those used at the national ones (e.g. integrated GIS systems);

- development of sustainable strategy at local, national and European levels based on the analysis of countermeasures for relevant accident scenarios;
- development of health surveillance procedures;
- development of monitoring strategies, processes and tools (thanks to an optimised used of resources such as mobile units, trans-border information exchange and monitoring crowdsourcing).

Table 23: Means and standard deviations in answers for topics related to NERIS Research area 3, Key topic 5 - Improving of the decision-making processes

NERIS Research area 3 , Improving of the decision-making processes		Mean	Std.
Assessment of and communication on uncertainties	Feasibility	62	23
	Importance	75	21
Coupling of Decision Support Systems with Command and Control systems	Feasibility	59	23
	Importance	70	19
Improvement of decision-making processes through the development of guidances and multi-criteria analysis decision-aiding tools_ taking into account the feedback from stakeholder processes (e.g. from Fukushima)	Feasibility	66	21
	Importance	76	18
Development of serious gaming (for stakeholder education and training)	Feasibility	69	22
	Importance	65	24
Revision of European handbooks considering malevolent acts	Feasibility	73	18
	Importance	61	23
Development of tools for the usage at the local level_ which are compatible with those used at the national ones (e.g. integrated GIS systems)	Feasibility	68	19
	Importance	71	18
Development of sustainable strategy at local_ national and European levels based on the analysis of countermeasures for relevant accident scenarios	Feasibility	69	20
	Importance	74	19
Development of health surveillance procedures	Feasibility	68	17
	Importance	72	19
Development of monitoring strategies_ processes and tools (thanks to an optimised used of resources such as mobile units_ trans-border information exchange and monitoring crowdsourcing)	Feasibility	74	18
	Importance	80	16

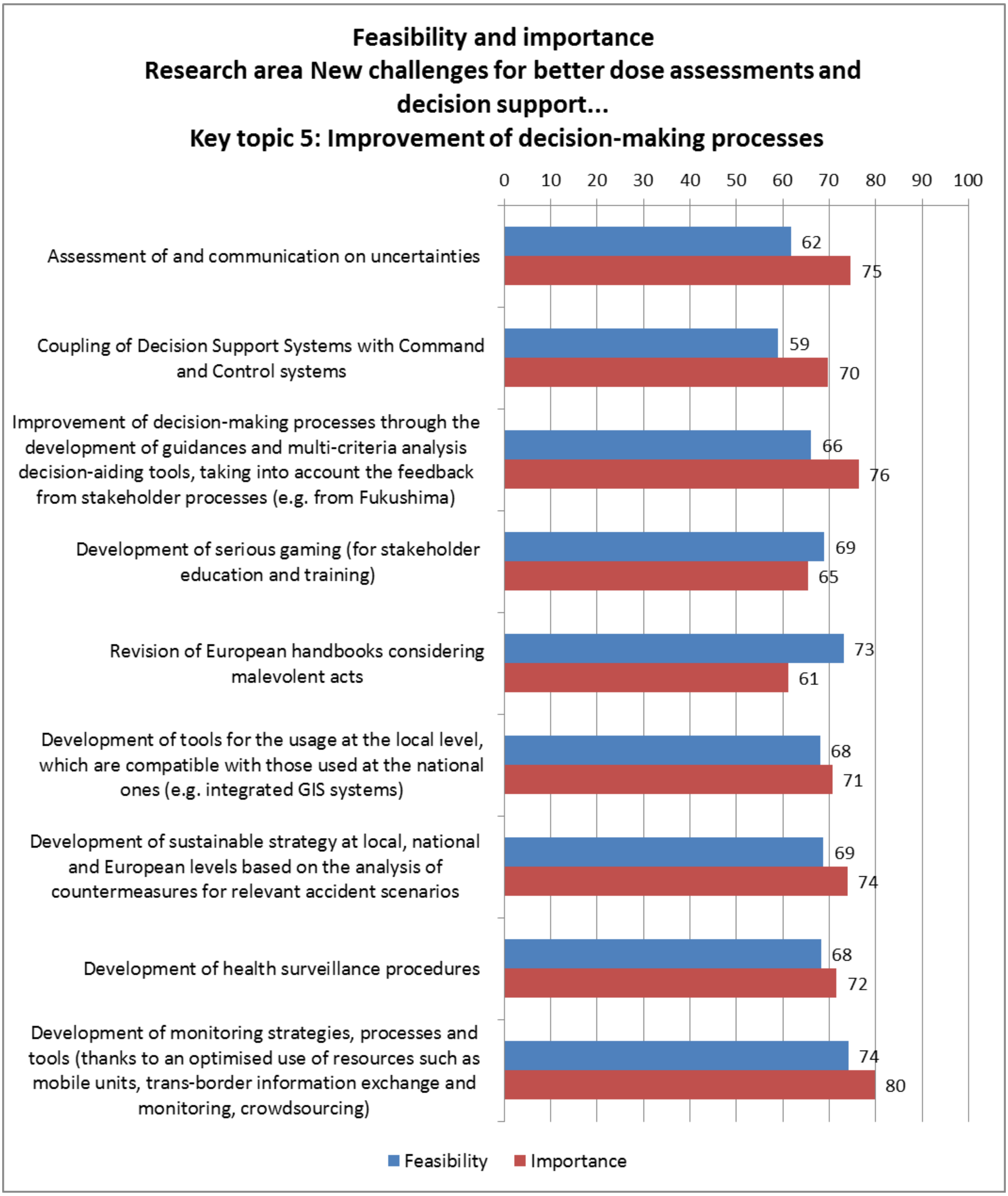


Figure 25: Feasibility and importance for topics related to NERIS Research area 3, Key topic 5 - Improving of the decision-making processes

Table 24: Additional issues related to Improving of the decision-making processes suggested by respondents

	Research area 2: New challenges for better dose assessments and decision support based on improved knowledge: source term, scenarios, etc **Key topic 5 Improving of the decision-making processes aims at improving decision processes.**
	Are there any additional issues for improving decision-making processes? Please specify.
	Comments: 1
1	Realtime systems to improve decision making with experts.

3.6.6 NERIS Research Area 3, Key topic 6: Stakeholder management and dialogue

Stakeholder management and dialogue aims at improving the acceptability and social robustness of emergency response, ensuring that stakeholders are involved in decisions that impact on their lives. Expected results are:

- To maintain the inclusion of social aspects of emergency response and stakeholder engagement.
- A greater recognition of the importance of stakeholder and public engagement.
- To improve understanding of the factors and criteria for successful stakeholder engagement.

Respondents were asked to indicate the importance/feasibility (High-Low; Importance: High-Low) of the topics related to Stakeholder engagement and dialogue:

- Defining stakeholders and framing problems (identifying the roles, responsibilities and co-operation among national/regional/local stakeholders).
- Stakeholder engagement database (lessons learned from past experiences).
- Development of guidance on information and participation of affected population.
- Guidelines and strategies on the contaminated goods management.

Table 25: Means and standard deviations in answers for topics related to NERIS Research area 3, Key topic 6 - Stakeholder management and dialogue

NERIS Research area 3, Stakeholder management and dialogue		**Mean**	**Std.**
Defining stakeholders and framing problems (identifying the roles_ responsibilities and co-operation among national/regional/local stakeholders)	Feasibility	65	21
	Importance	71	20
Stakeholder engagement database (lessons learned from past experiences)	Feasibility	69	20
	Importance	71	19
Development of guidance on information and participation of affected population	Feasibility	69	19
	Importance	74	18
Guidelines and strategies on the contaminated goods management	Feasibility	71	18
	Importance	78	18

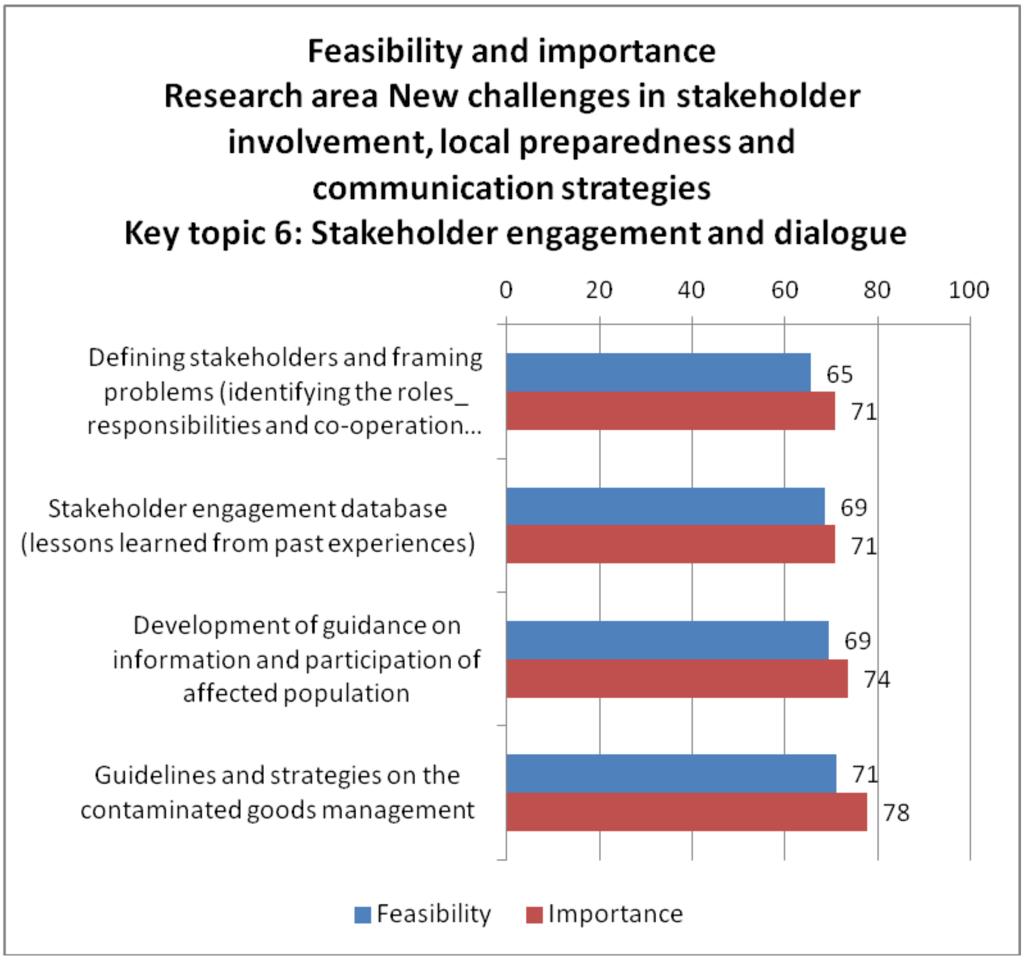


Figure 26: Feasibility and importance for topics related to NERIS Research area 3, Key topic 6 - Stakeholder management and dialogue

3.6.7 NERIS Research Area 3 - Key Topic 7; Use of social media and networking

- Use of social media and networking aims at better understanding the ways in which social media and other media are used in the flow of information and communication. Expected results are to improve preparedness for media and social media communication.
- Respondents were requested to indicate the importance/feasibility of the topics related to Use of social media and networking.
- Analysis of public behaviour response (i.e. understand how the public reacts and which information related to people's behaviours can be used by local-national tools to improve response).
- Assessment of the mechanisms by which the public gains information in media and social media.
- Assessment of important factors for social trust in emergency situations.

Table 26: Means and standard deviations in answers for topics related to NERIS: Use of social media and networking

NERIS, Key topic 7		Mean	Std.
Analysis of public behaviour response (i.e. understand how the public reacts and which information related to people's behaviours can be used by local-national tools to improve response)	Feasibility	64	21
	Importance	74	19
Assessment of the mechanisms by which the public gains information in media and social media	Feasibility	64	20
	Importance	68	20
Assessment of important factors for social trust in emergency situations	Feasibility	65	19
	Importance	76	18

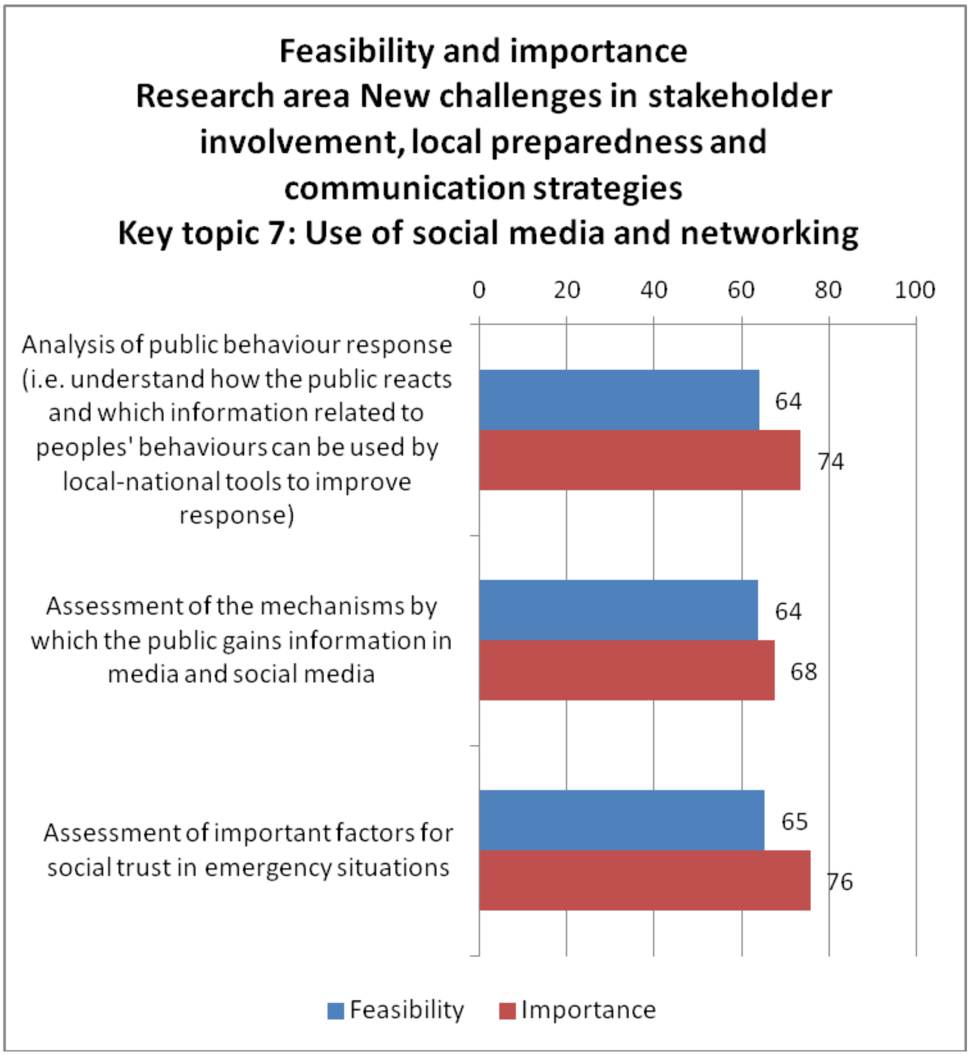


Figure 27: Feasibility and importance for topics related to NERIS: Use of social media and networking

Table 27: Additional issues related to use of social media and networking suggested by respondents

	Research area 3: New challenges in stakeholder involvement, local preparedness and communication strategies **Key topic 6 Stakeholder management and dialogue aims at improving the acceptability and social robustness of emergency response, ensuring that stakeholders are involved in decisions that impact on their lives**
	Are there any additional issues for improving stakeholder engagement and dialogue? Please specify.
	Comments: 3
1	Include NGOs and the public. Press
2	Need to establish use and experience of social media! Everyone will be using it and the "Authorities" need to engage and provide authoritative information to counter all the wrong information that will be spread!
3	Education and training of stakeholders affected or involved in the management of contaminated goods but without radiation protection knowledge.

Table 28: Additional issues related to the improvement of preparedness for media and social media communication

	Research area 3: New challenges in stakeholder involvement, local preparedness and communication strategies
	Are there any additional issues related to the improvement of preparedness for media and social media communication? Please specify.
	Comments: 2
1	Social media can be used as a feedback mechanism for the administrators for preparedness activities and media management in case of emergencies.
2	Need help in how best to use social media!

The content of all emergency and recovery preparedness free texts is reported in annex 1 (pp 94)

3.7 DOSIMETRY (EURADOS)

The European Radiation Dosimetry Group (EURADOS) consists of a self-sustainable network whose aim is to promote research and development and European cooperation in the field of dosimetry of ionising radiation.

The EURADOS SRA is expected to contribute to identify future research needs in radiation dosimetry. This SRA is based on input from EURADOS Working Group members and takes into account the comments from consultations within Eurados members.

The present document formulates five visions in dosimetry and defines – for each vision – two to five challenges, leading to a total of 18 challenges.

3.7.1 Vision 1: Towards updated fundamental dose concepts and quantities

Respondents were requested to assess the importance and feasibility of challenges (High-Low) related to Eurados SRA Vision 1: Towards updated fundamental dose concepts and quantities.

- To improve understanding of spatial correlations of radiation interaction events.
- To quantify correlations between track structure and radiation damage.
- To improve understanding of dosimetry and biokinetics of internal emitters.
- To Update Operational Quantities for External Exposure.

Table 29: Means and standard deviations in answers for topics related to dosimetry: Towards updated fundamental dose concepts and quantities

Dosimetry, Towards updated fundamental dose concepts and quantities		Mean	Std.
To improve understanding of spatial correlations of radiation interaction events	Feasibility	60	16
	Importance	69	19
To quantify correlations between track structure and radiation damage	Feasibility	60	20
	Importance	73	18
To improve understanding of dosimetry and biokinetics of internal emitters	Feasibility	64	19
	Importance	75	17
To Update Operational Quantities for External Exposure	Feasibility	68	17
	Importance	66	21

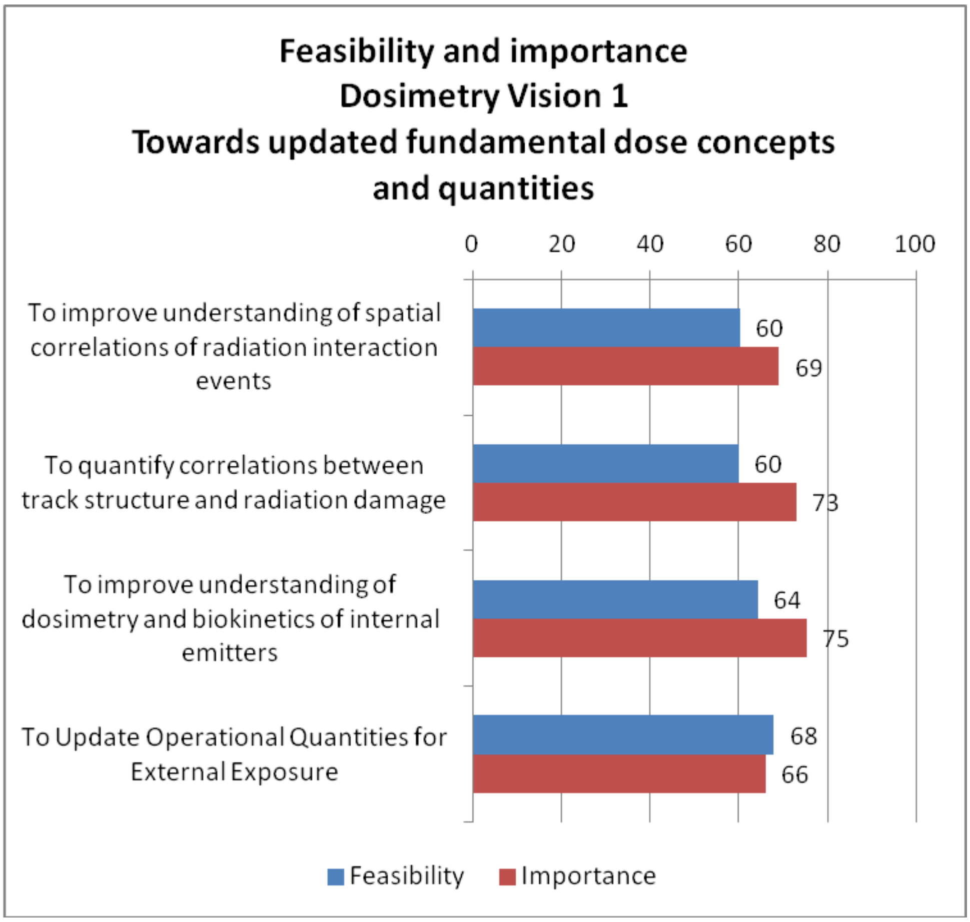


Figure 28: Feasibility and importance for topics related to dosimetry: Towards updated fundamental dose concepts and quantities

3.7.2 EURADOS Vision 2: Towards improved radiation risk estimates deduced from epidemiological cohorts

Respondents were asked to assess the importance and feasibility of challenges related to Eurados SRA Vision 2: Towards improved radiation risk estimates deduced from epidemiological cohorts.

- To explore exposure pathways not yet considered or validated.
- To improve retrospective dosimetry for exposure pathways already considered.

Table 30: Means and standard deviations in answers for topics related to dosimetry: Towards improved radiation risk estimates deduced from epidemiological cohorts

Dosimetry, Towards improved radiation risk estimates deduced from epidemiological cohorts		Mean	Std.
To explore exposure pathways not yet considered or validated	Feasibility	56	20
	Importance	63	22
To improve retrospective dosimetry for exposure pathways already considered	Feasibility	65	20
	Importance	75	17

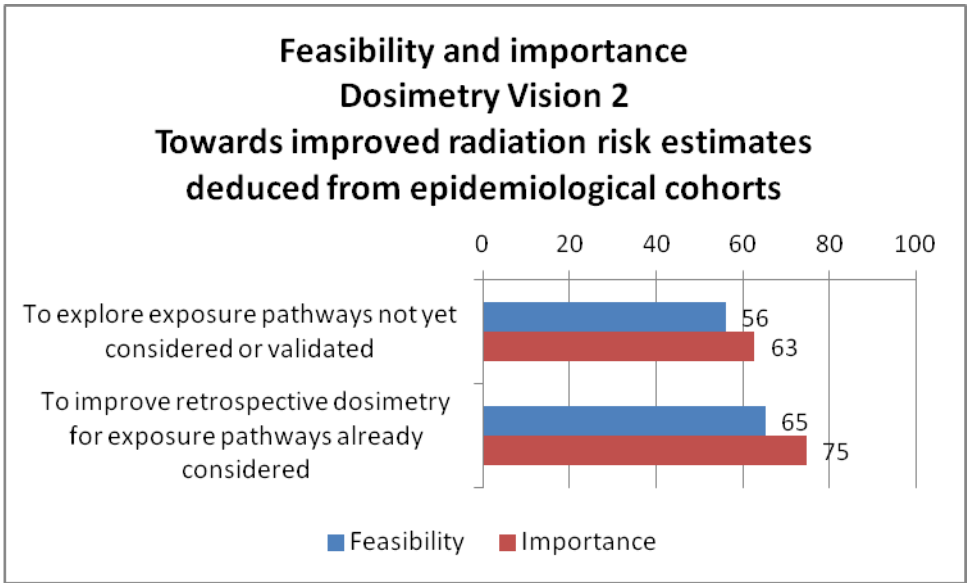


Figure 29: Feasibility and importance for topics related to dosimetry: Towards improved radiation risk estimates deduced from epidemiological cohorts

3.7.3 Vision 3: Towards an efficient dose assessment in case of radiological emergencies

Respondents were requested to assess the importance and feasibility of challenges related to Eurados SRA Vision 3: Towards an efficient dose assessment in case of radiological emergencies.

- To identify and characterize new markers of exposure.
- To develop strategies and methods to increase measurement capacity.
- To quantify doses after accidental internal contamination.

Table 31: Means and standard deviations in answers for topics related to dosimetry: Towards an efficient dose assessment in case of radiological emergencies

Dosimetry, Towards an efficient dose assessment in case of radiological emergencies		Mean	Std.
To identify and characterize new markers of exposure	Feasibility	58	20
	Importance	75	19
To develop strategies and methods to increase measurement capacity	Feasibility	68	19
	Importance	74	19
To quantify doses after accidental internal contamination	Feasibility	65	19
	Importance	76	17

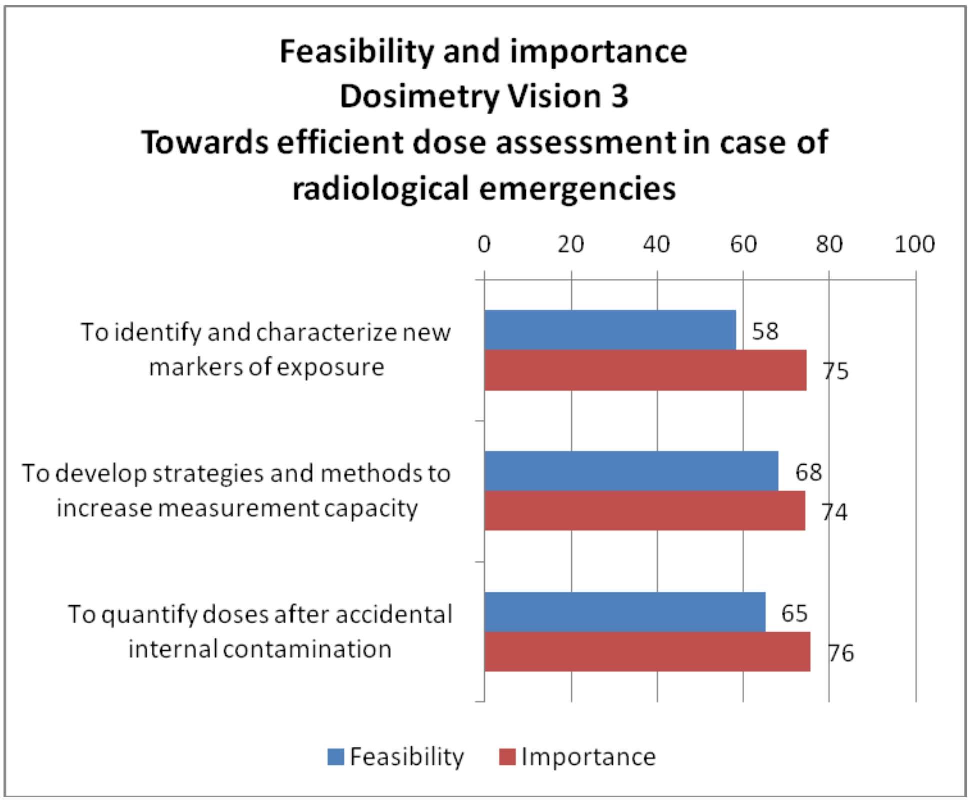


Figure 30: Feasibility and importance for topics related to dosimetry: Towards an efficient dose assessment in case of radiological emergencies

3.7.4 Vision 4: Towards an integrated personalized dosimetry in medical applications

Respondents were requested to assess the importance and feasibility of challenges related to Eurados SRA Vision 4: Towards an integrated personalized dosimetry in medical applications.

- To improve out-of-field dosimetry for photon and particle therapy.
- To improve dosimetry in modern external beam radiotherapy.
- To improve internal microdosimetry in radiotherapy and medical imaging.
- To optimize dose estimations in interventional radiology.
- To establish reliable patient dosimetry in CT examinations.

Table 32: Means and standard deviations in answers for topics related to dosimetry: Towards an integrated personalized dosimetry in medical applications

Dosimetry, Towards an integrated personalized dosimetry in medical applications		Mean	Std.
To improve out-of-field dosimetry for photon and particle therapy	Feasibility	68	18
	Importance	72	20
To improve dosimetry in modern external beam radiotherapy	Feasibility	71	16
	Importance	72	20
To improve internal microdosimetry in radiotherapy and medical imaging	Feasibility	64	17
	Importance	73	20
To optimize dose estimations in interventional radiology	Feasibility	72	16
	Importance	78	17
To establish reliable patient dosimetry in CT examinations	Feasibility	74	17
	Importance	78	17

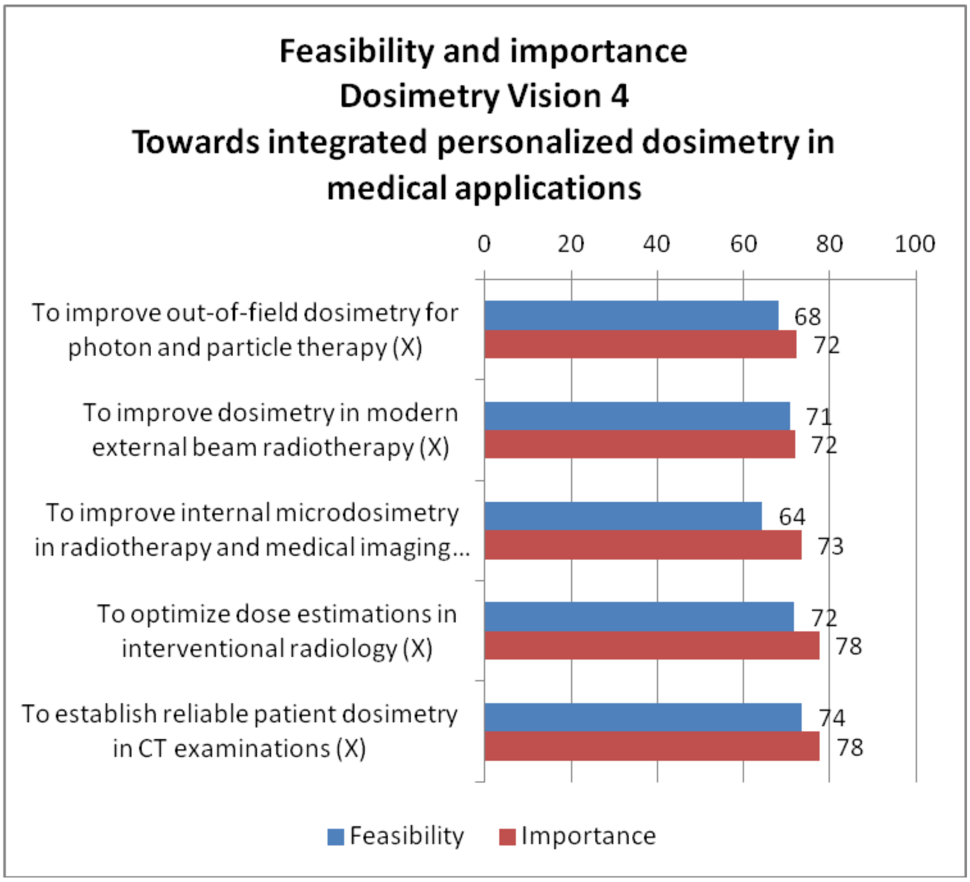


Figure 31: Feasibility and importance for topics related to dosimetry: Towards an integrated personalized dosimetry in medical applications

3.7.5 Vision 5: Towards an improved radiation protection of workers and the public

Respondents were requested to assess the importance and feasibility of challenges related to Eurados SRA Vision 5: Towards an improved radiation protection of workers and the public.

- To improve, validate and implement new biokinetic models.
- To develop calibration procedures for partial body counters.
- To develop accurate and on-line personal dosimetry for workers.
- To improve neutron dosimetry techniques.
- To include nuclide-specific information in environmental monitoring.

Table 33: Means and standard deviations in answers for topics related to dosimetry; Towards an improved radiation protection of workers and the public

Dosimetry, Towards an improved radiation protection of workers and the public		Mean	Std.
To improve validate and implement new biokinetic models	Feasibility	59	20
	Importance	70	21
To develop calibration procedures for partial body counters	Feasibility	65	18
	Importance	66	20
To develop accurate and on-line personal dosimetry for workers	Feasibility	70	19
	Importance	68	22
To improve neutron dosimetry techniques	Feasibility	62	19
	Importance	70	21
To include nuclide-specific information in environmental monitoring	Feasibility	64	19
	Importance	67	21

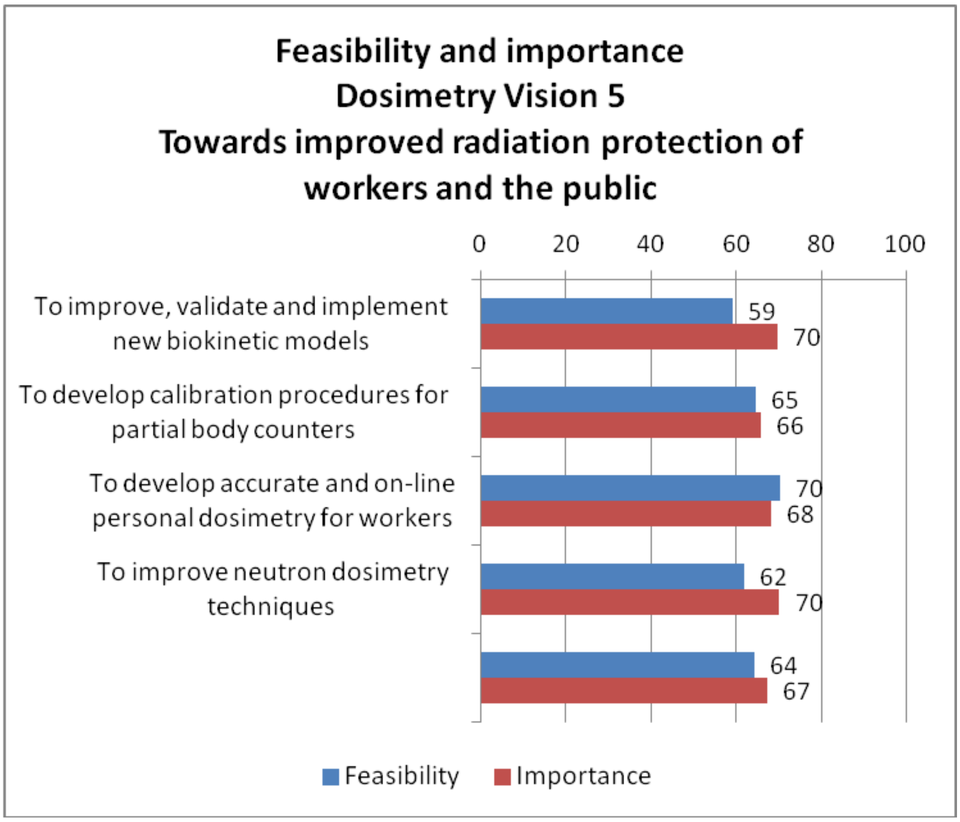


Figure 32: Feasibility and importance for topics related to dosimetry: Towards an improved radiation protection of workers and the public

3.8 RADIATION PROTECTION CONCERNS US ALL – QUESTIONS ON ETHICS

Given the nature of radiological risk, the question of whether the use of nuclear technology is justified in a specific context has to take into account many uncertainties and unknowns. On the one hand, there are scientific uncertainties that complicate the quantification of low dose effects. On the other hand, safety and security measures can never exclude human error and malevolence or fully anticipate potentially dangerous events and their development over time.

Whether in the context of medical applications, industrial uses or energy production, the justification of the use of nuclear technology can thus only partly rely on scientific evidence and needs to take into account value judgements of all concerned, either having a mandatory responsibility or being a potentially affected person (e.g. patients, citizens, scientists, workers, doctors, engineers, managers, NGO representatives and policy makers). In this sense, the ethics of justification and radiation protection relate to taking value judgements into account in a responsible way, respecting human dignity, capacities and autonomy and the value of the environment, and acting accordingly.

Together with the ethical aspects dealing with adverse or unintended effects (e.g. severe normal tissue reactions to radiotherapy and post-accident measures), these judgements make up the ethical dimension of radiation protection in an occupational context and in society at large. Respondents needed to answer on questions related to these aspects.

28 respondents out of the total 45 agreed with the understanding of ethics in relation to radiation protection as presented above and 15 respondents did not (2 respondents had no opinion).
38 respondents agreed that ethical aspects related to the use of nuclear technology should be included among future research priorities; while 5 respondents did not agree (4 respondents did not have an opinion).

Next, respondents were asked to indicate which thematic areas related to ethics they found relevant to be considered in future research. From the figure below it can be seen that all topics proposed were considered by the majority of respondents as relevant or highly relevant.

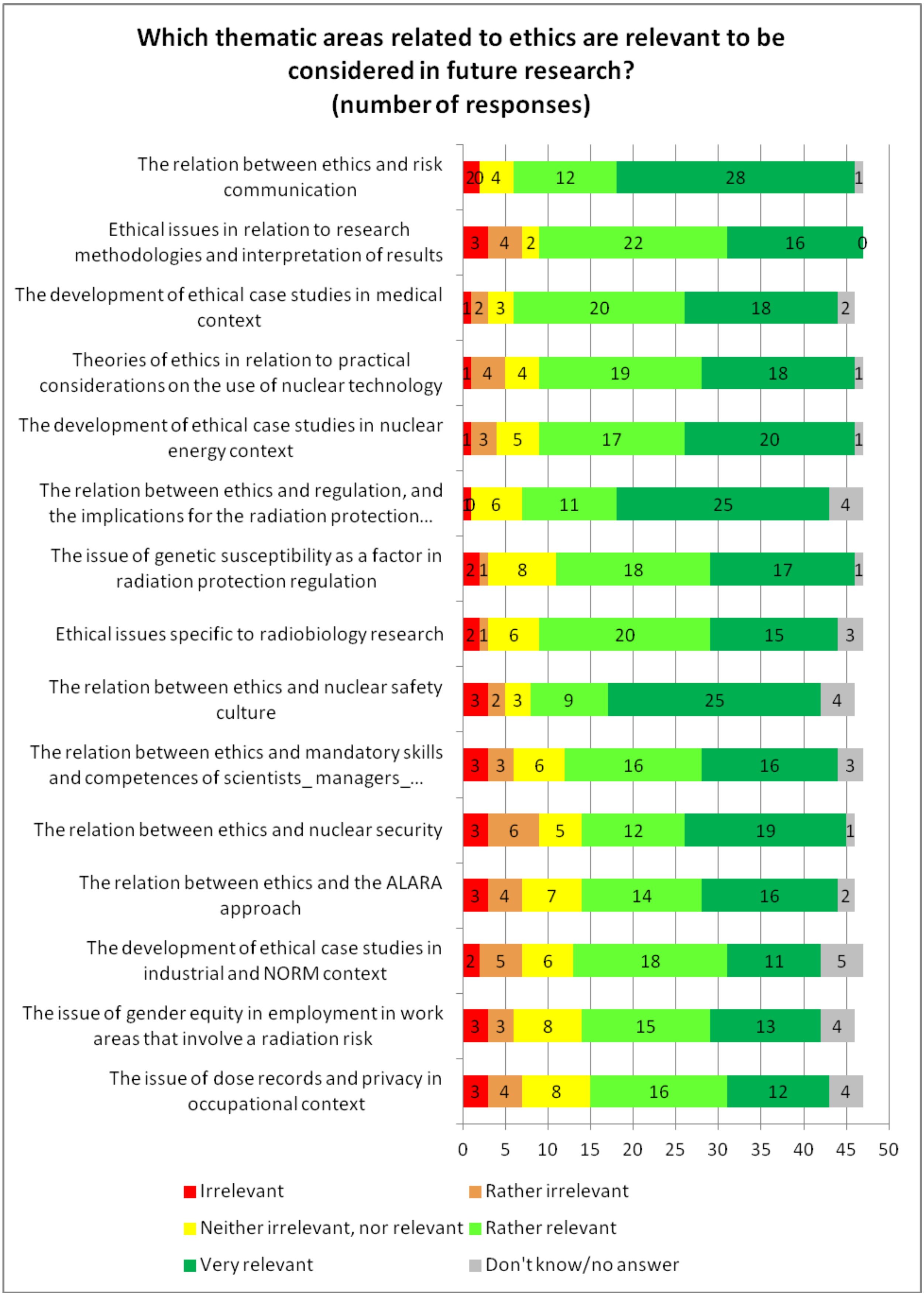


Figure 33: Thematic areas related to ethics relevant to be considered in future research

24 respondents stated that taking into account the various possible understandings of ethics in relation to the use of nuclear technology and the various thematic areas that may be considered relevant in this sense, a separate Strategic Research Agenda (SRA) related to ethics would be useful, 9 respondents did not agree with this and 13 respondents did not have an opinion.

The next question enquired whether, in case the respondent agreed that a SRA related to ethics were useful, they would recommend considering all application contexts (medical, energy, industrial) in one SRA or they thought it was better to develop a separate SRA for each application context. The opinions were divided:

- 20 respondents recommended a common SRA on ethics considering all application contexts (medical, energy, NORM/industrial);
- 17 respondents recommended separate SRA's on ethics for distinct application contexts (medical, energy, NORM/industrial);
- 8 respondents did not have an opinion.

Conclusion:

The level of response suggests that there is a substantial interest in ethic issues within the community surveyed, and issues surrounding ethics in relation to risk communication, regulation and safety culture were considered to be of greatest relevance.

Table 34: Other thematic areas related to ethics respondents found relevant to be considered in future research

	Are there any other thematic areas related to ethics you would find relevant to be considered in future research? Please specify.
	Comments: 8
1	Ecoethics and sustainable development
2	Relation between ethics and economic gains.
3	Just a comment - in medical applications/research, would expect ethical considerations to be undertaken routinely. Therefore see more value added in focusing on the other areas indicated.
4	Role and responsibility of society in helping forward radiation protection research. i.e. facilitating access to the data (medical records. dose records. etc) under condition that individual data protection aspects are considered.
5	I think this picture of ethics is rather outdated. Today’s ethical concerns cover the environment also. i.e environmental aspects cannot be isolated from other ethical concerns.
6	Communications with stakeholders!
7	The ethical dimension of the radiation protection system, with a focus on values and objectives.
8	Development of a broad consent that allows international biological research of biological specimen in regard to radiation risk research.

3.9 RISK COMMUNICATION AND RISK PERCEPTION

Despite 50 years of extensive research, risk perception and risk communication are relatively new disciplines in social sciences and are barely applied in the field of low doses of ionising radiation. Moreover, it was already indicated in the OPERRA project that collaboration between social, human and natural sciences should be encouraged.
The eSurvey allowed collecting opinions of 91 respondents in what concerns the quality of communication with the public about risk associated with low doses of ionising radiation.

First the respondents were asked whether they were satisfied with the way that selected actors communicate and provide information about low doses of ionising radiation.

In general, the respondents were the most satisfied with communication performed by research institutes and state agencies, followed by the nuclear industry and they were the least satisfied with communication by mass media, family doctors and dentists and the medical personnel in hospitals. It is important to notice that most of the respondents work for scientific institutions (e.g. universities, research institutes…) or for regulatory bodies or controlling authorities; thus they are in general satisfied with their own communication and less satisfied with the communication by others.

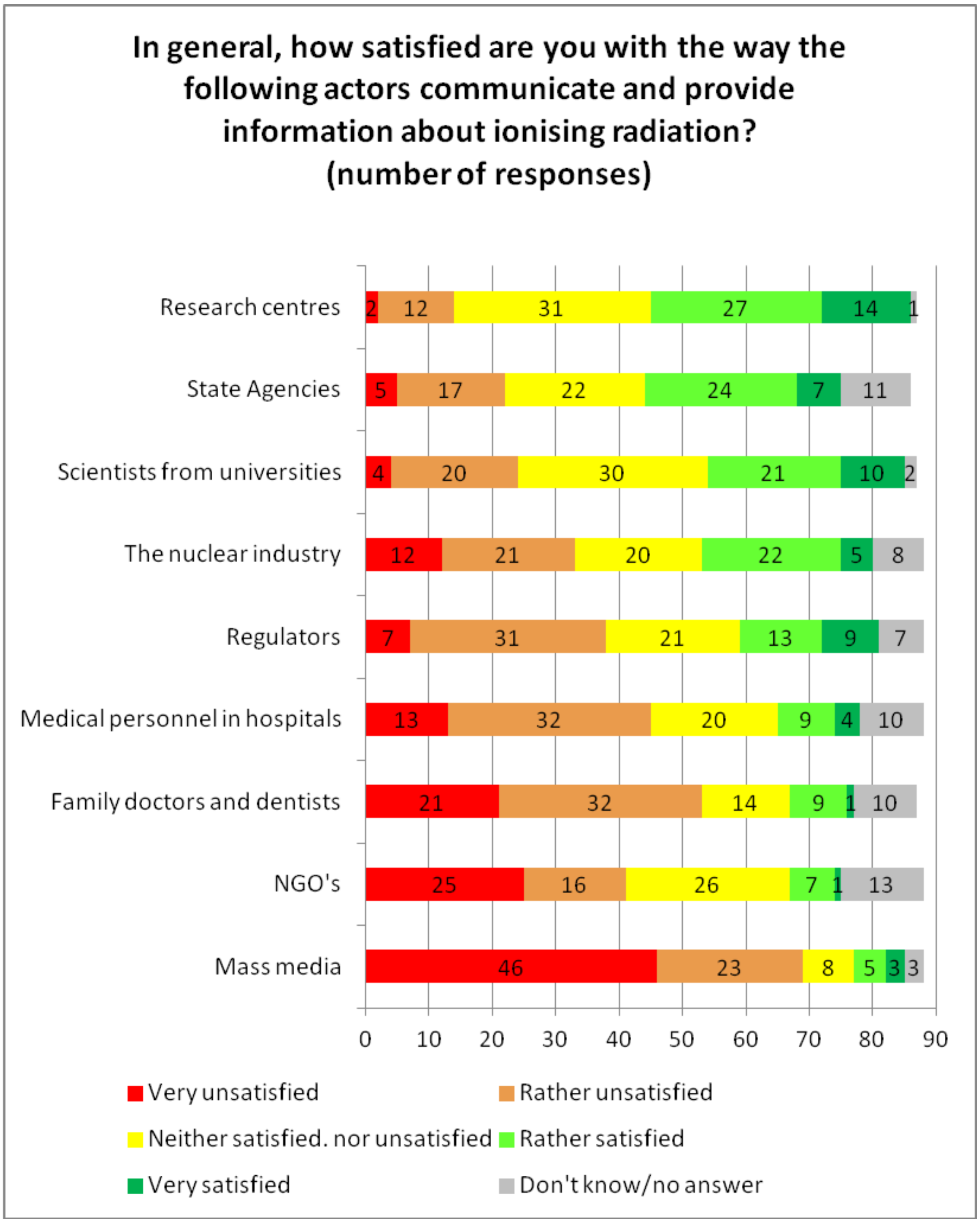


Figure 34: Satisfaction with the way of selected actors communicate and provide information about low doses of ionising radiation

Next, respondents were asked to indicate how much they agree or disagree with a number of statements related to risk communication and risk perception of low doses of ionising radiation, using the response scale ranging from completely disagree (1) to completely agree (5).

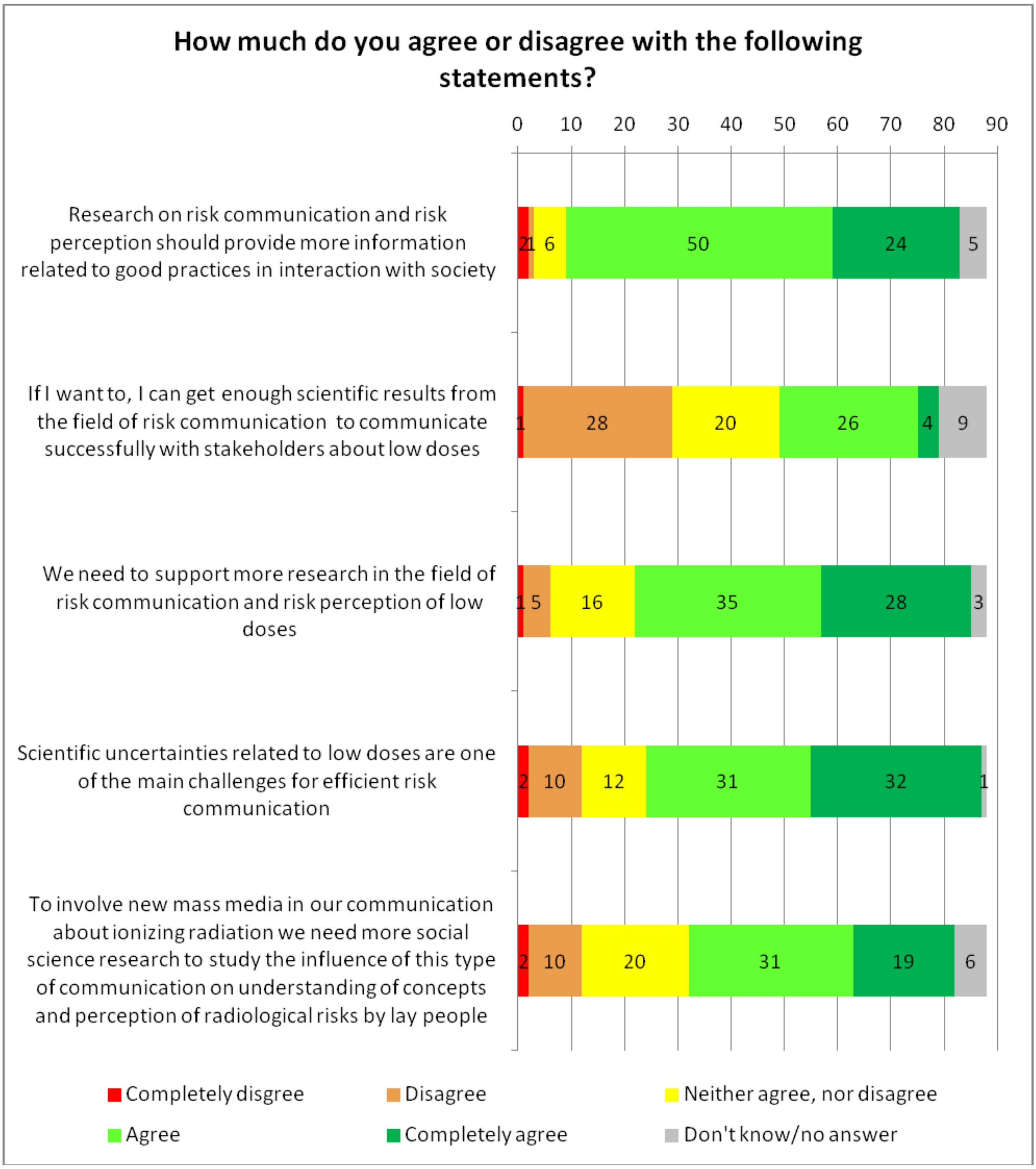


Figure 35: Level of agreement with the statements related to communication and risk perception of low doses of ionising radiation

Almost all respondents agreed that research on risk communication and risk perception should provide more information related to good practices in interaction with society. 63 respondents out of 88 agreed that there is a need to support more research in the field of risk communication and risk perception of low doses. 29 respondents stated that if they wanted to, they could get enough scientific results from the field of risk communication to communicate successfully with stakeholders about low doses. Scientific uncertainties related to low doses were recognised by 63 respondents out of 88 as one of the main challenges for efficient risk communication. 50

respondents agreed or strongly agreed that there is a need for more social science research directed to new mass media, in order to study the influence of this type of communication on the understanding of complex concepts and the perception of radiological risks by lay people. In general, 57 respondents agreed that further research into risk communication would be beneficial to radiation protection, 13 respondents disagreed with the statement and 18 respondents did not have an opinion. 59 respondents also agreed that it would be useful to develop a strategic research agenda for risk communication in radiation protection, while 9 respondents did not agree and 19 did not have an opinion.

Conclusion:

The 90 responses in this focus area indicate that it is of greater interest than ethical issues, although there is overlap. Responses suggest a scepticism on messages form mass media and NGOs by comparison with research institutes. The most important area for research was perceived to be in relation to communication with wider society.

Table 35: Issues and topics related to risk perception and risk communication that would require new or more research in the field of low doses

	Are there issues and topics related to risk perception and risk communication that would require new or more research in the field of low doses? Please specify.
	Comments: 15
1	Safety culture as a whole.
2	Need to involve experts in sociology and risk communication and not researchers from nuclear who do not have that education.
3	My experience and feeling suggest that improvements in risk communication depend more on practical experience and 'good practice' than on scientific research. I think research has told us what we need to know to be able to communicate satisfactory.
4	Basic exposure to complement exposures expected in standard radiology (general x-ray) procedures.
5	People just do not believe due to permanent wrong information from media and partly NGOs. People like the sensation of bad news. Better education to students and teachers.
6	More sophisticated insight into the processes and how information is subsequently acted upon by different actors. Multi-stakeholder processes are poorly understood and often misused.
7	Actually not, the main investment is education and build bridges to other hazards
8	The point is that there risk communications is an established science that the radiation protection profession needs to reach out to in order to learn from them. We don't need more research. we need to partner with these professionals!
9	Risk communication for workers; perception between medical and nuclear energetics. even military and background doses; training of young people in secondary school studies; etc.
10	Research and analysis on the different modality of communication (on the basis of numbers. percentage. comparison with other risk....).
11	Always say the truth as viewed from an expert perspective... not trying to minimize/maximize risk. not shading uncertainties
12	It would be useful to differentiate risk and concern (i.e. public concern is not an indicator nor a predictor of risk). Related to the above, the public is often exposed to potentially worrying news: this needs to be studied. Interestingly, this issue was defined early by WHO experts: "Although the case in favour of concealing nothing from the public appears to be unanswerable, there is, nevertheless, a duty to study the psychological principles of the presentation of anxiety-raising information in relation to the capacity of the public to endure it. (WHO. 1958. p.44)" A lot has been done about the first half of the above statement -- but much less about the second half.
13	Improved inclusion of radiation topics in educational process would be beneficial to radiation

	protection.
14	Individuals' behaviour (consumer behaviour. health related behaviour. etc.) associated with low radiation. Evaluation of behavioural modification strategies. Social diffusion of information about radiation.

Table 36: Institutes that perform research related to risk perception and risk communication in the field of low doses of radiation identified by respondents

	Do you know research institutes that perform research related to risk perception and risk communication in the field of low doses of radiation? If yes, please indicate these institutions and, if possible, specific departments and/or researchers.
	Comments: 15
1	SCK-CEN Mol IRSN University of Oslo University of Landcaster
2	French IRSN (http://www.irsn.fr/FR/Pages/Home.aspx) and french CEPN (http://www.cepn.asso.fr) has long experience in this field and have published many articles on the subject of risk perception related to nuclear energy.
3	SCK.CEN
4	Leibnitz University of Hannover - Centre for radiation and radioecology (name?)
5	KSU at Studsvik FOI sweden
6	Yes, but there are colleagues at SCK-CEN who are better positioned to answer this question. I need to go and dig: first to my mind. SCK-CEN. IRSN. Univ Ljubljana, but if I dig a bit I could find more.
7	You need to work with Vincent Covello. See the Program for IRPA 13 and his presentation!!!!
8	I don’t know any. It is difficult to find this information.
9	Some institutions in the different European country, well known in the community, and moreover little research groups.
10	SCK-CEN IRSN
11	Yes: SCK/CEN. Mol. Belgium (T. Perko)
12	A related article (about radiofrequencies. but some concepts of risk perception and communication could be useful to low dose issues): Poumadere. M.; Perrin. A. (2013) Risk Assessment of Radiofrequencies and Public Information. Journal of Risk Analysis and Crisis Response Vol. 3. No. 1 (3-12) The French version was published after a presentation at the annual meeting of the SFRP (French Radioprotection Society): Poumadere. M. & Perrin. A. (2011). Exposition socio-cognitive et evaluation des risques : le cas de la phonie mobile. Radioprotection. 46 (1) pp. 59-73.
13	IRSN SCK
14	State Institution National Research Center for Radiation Medicine of the National Academy of Medical Sciences of Ukraine. V. A. Prilipko. Iu. Iu. Ozerova. M. M. Morozova. K. K. Shevchenko
15	SCK-CEN

3.10 EDUCATION AND TRAINING

Nowadays, the offer of academic and professional education and training programmes devoted to the science and engineering of nuclear technology, radiobiology, radiation protection and safety culture in European context is wide and well established. While European education and training policy is concerned with streamlining, integration and cooperation in the interest of quality assurance and effective use of financial and human resources, there remains the need for high-level specialised courses adapted to the specific needs of researchers, engineers, managers and mandatories responsible for radiation protection and safety culture.

The following questions aimed at capturing respondents' opinions on education and training matters in general and with respect to their own professional context. A total of 103 respondents answered these questions related to education and training.

59 respondents stated that education and training needs are met by the existing courses/materials available in Europe, 17 respondents stated the contrary and 27 respondents don't have an opinion.

Respondents were next asked to indicate on a scale ranging from irrelevant (1) to very relevant (5), which education and training matters they thought relevant to be considered in future research.

- Harmonisation of qualification standards.
- The development of ethical case studies for education and training purposes.
- The integration of courses on ethical and political aspects of technology assessment in standard academic programmes for scientists and engineers.
- The integration of courses on risk perception and risk communication of ionising radiation in standard academic programmes for scientists and engineers.

The respondents found that the most relevant education and training issues were the "Harmonisation of qualification standards" and "The integration of courses on risk perception and risk communication of ionising radiation in standard academic programmes for scientists and engineers".

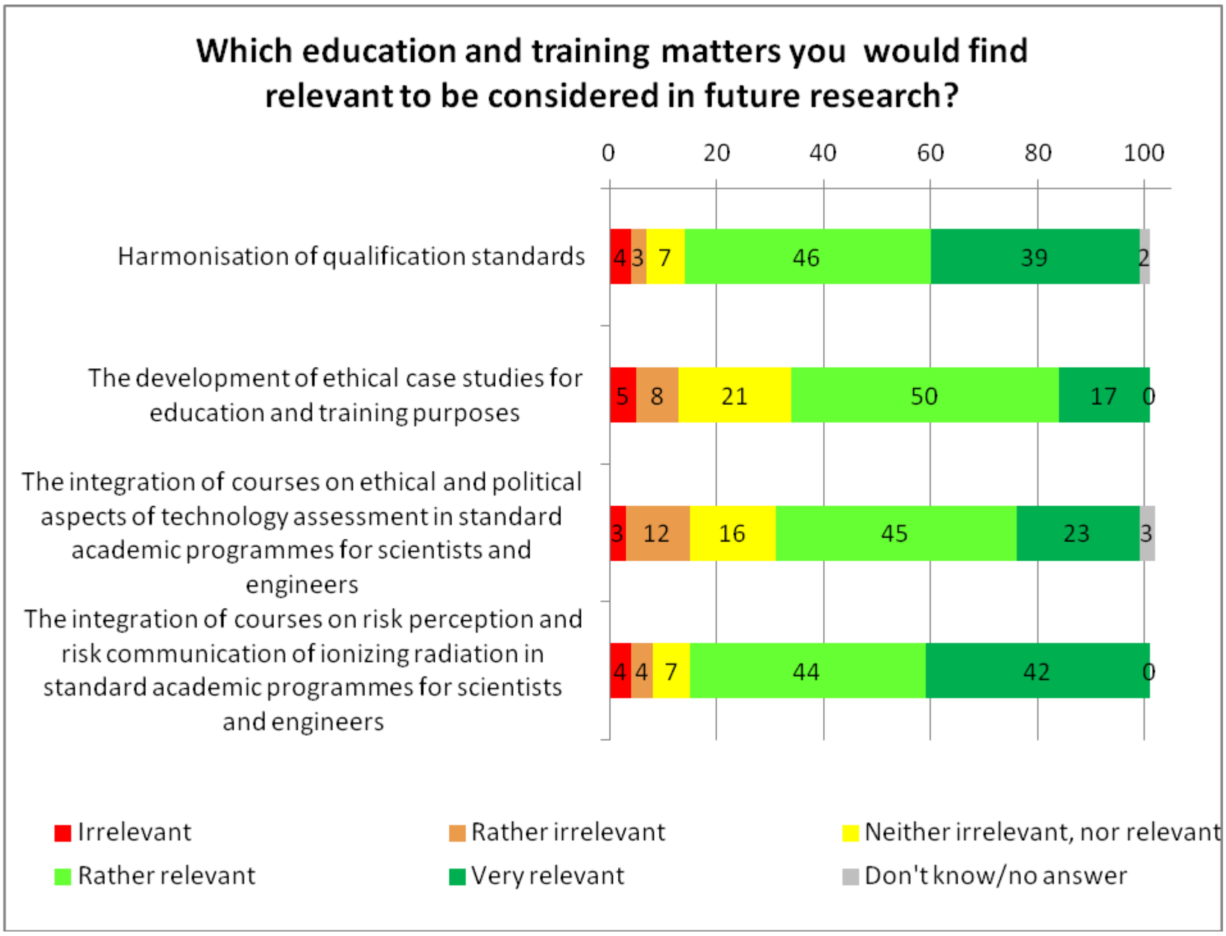


Figure 36: Relevance of education and training matters to be considered in future research

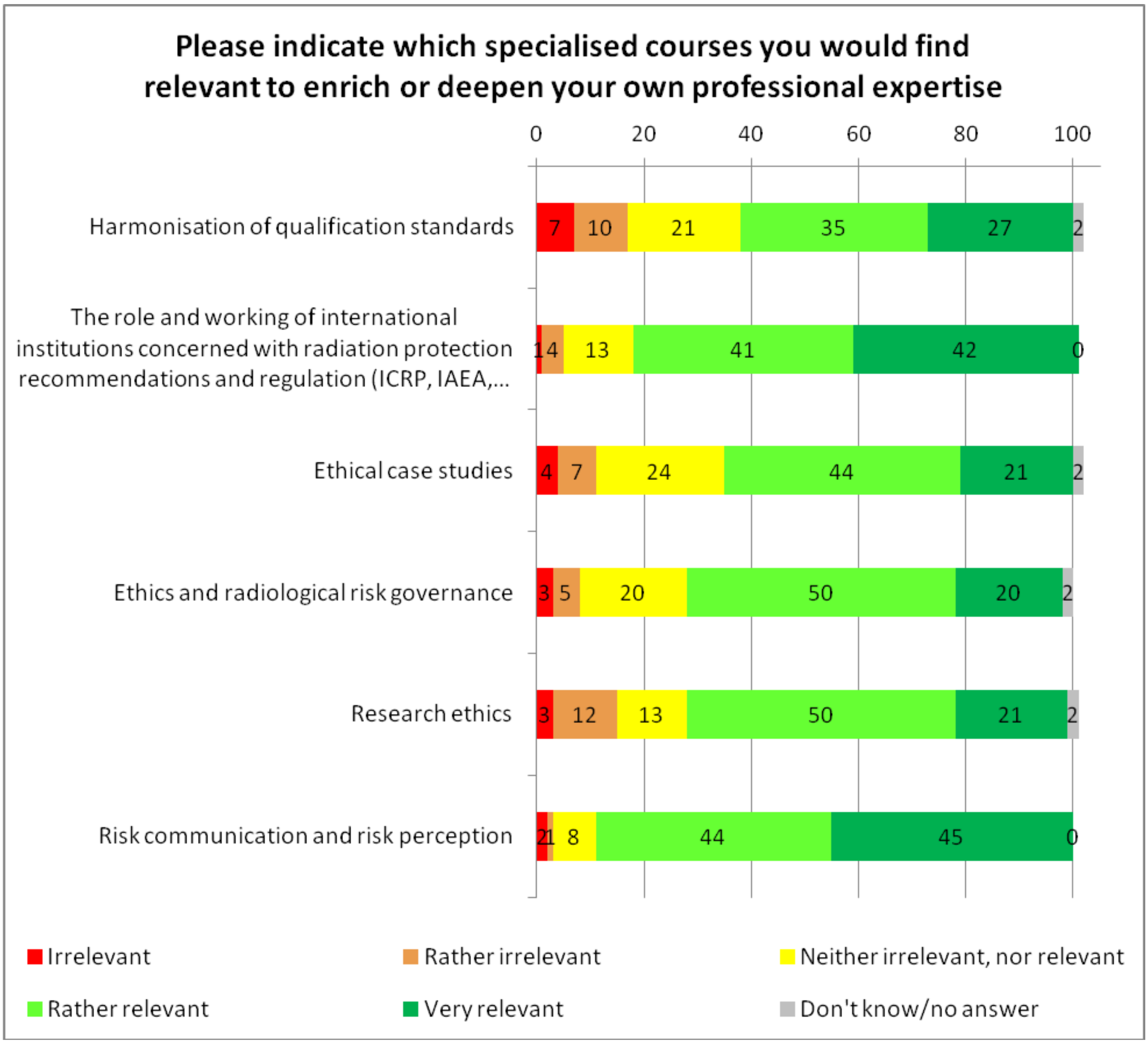


Figure 37: Need for specialised courses

Table 37: Suggestions for additional training courses/materials that would benefit radiation protection

	Do you have suggestions for additional training courses/materials that would benefit radiation protection? Please specify below.
	Comments: 27
1	Using practical examples
2	More detailed and practical trainings
3	General radiation protection principles (Understanding of key issues is decreasing, this would be important also to understand the context of protection of the environment). Assessment methodologies for human doses both for routine releases and waste management (risk assessment) Safety regulation (we need a holistic view going across different areas. eg nuclear vs. non-nuclear. waste disposal and transport etc.)
4	- Concepts of Epidemiology studies - Fundamentals on Internal Dosimetry
5	Courses on interconnections between non-targeted and targeted effects of radiation.

6	Training outside the nuclear sector to: - decision-makers - media - intervention teams (fire brigade. healthcare....) - practicians. family doctors
7	Specialized training material for doctors who traditionally have no or minimal training in radiation protection. Also training material for senior professionals who manage departments.
8	Suggest that all training each country be complementary of other nations to ensure basic information is equal and understandable no matter what nation is giving the training.
9	Radiation protection
10	Normal operation and safety assessment, predictions and scenarios and releases from point sources. Radioecology is too focused on accidents rather than estimates for new nuclear installation. Long term processes and dispersal from an underground point is almost lacking in most radioecology. The main part of that understanding is developed by e.g. Waste Management organisation. This gives doubts that this is independent research among the public.
11	Strong European master in radiation protection, dealing in part with general radiation protection issues (covered by the 4 platforms) and a year of specialisation in one of the radiation protection areas.
12	Since I don't know how other specialists are trained in radiation protection I can't tell for sure. How about a leaflet (like the cardiac resuscitation-leaflet) for newly trained physicians and medical students about radiation?
13	Add risk communications!
14	Extensive training of public emergency services; Training for secondary school pupils; Open training for citizens
15	Knowledge on the mechanism of radiation damage to stem cells and the consequences of that.
16	General public awareness programs Professional programs
17	Greater visibility
18	An advanced course for professionals intending to become radiation protection experts (technical and managerial dimensions)
19	Training in internal dosimetry and incorporation monitoring
20	Internal dosimetry training Emergency dosimetry
21	Basic education about radiation and RadProtect should be implemented already on elementary school and high school level.
22	Need of an European School of E&T in Radiation Protection
23	Lectures on numerical dosimetry. Lectures on anomalous diffusion.
24	Train the trainers Ionization Radiation Metrology Industry Norm (Natural Ocurring Radioactive Materials) Calibration of Equipment asociated to the Nuclear medicine
25	Current E&T efforts focus on young scientists. It would be useful to think about courses that for those who no longer qualify as young but who are not yet very senior either to help them set up international collaborations, for example.
26	Train the trainers Ionization Radiation Metrology Industry Norm (Natural Occurring Radioactive Materials) Calibration of Equipment associated to the Nuclear medicine
27	Practical Forums where practitioners could share experiences. Create forums of discussion with annual or every two years present meetings.

Table 38: Other education and training matters respondents would find relevant to be considered in future research

	Please specify which other education and training matters you would find relevant to be considered in future research?
	Comments: 12
1	Understanding the ecological and human health impacts.
2	Interdisciplinary courses on radiation protection issues.
3	The integration of courses on risk perception and risk communication of ionising radiation in standard academic programmes of medicine.
4	Efficacy evaluation of training materials and approaches. Social media.
5	Radiation protection.
6	1. Radiation protection mobile micro-eLearning Introduction: Learning in medicine has been changed during the last decade: The didactic format is steadily developing towards case-based teaching and learning, thus replacing traditional lectures. ELearning instruments, strongly focussing on the use of mobile devices, enhance the onsite presentations and discussions. The content is oriented on predefined outcomes. In the field of radiation protection, the traditional courses for delivering content prescribed by EU recommendations, are now supported by online course systems. The next step should be the creation of an eLearning environment to provide full access to the content. The aim of this project is to develop a tool for the use in the field of radiation protection and implement it on a European-wide scale. Methods: Basing on an already existing prototype of an app (Android based, soon available in Google Playstore), an eLearning tool should be developed for a case-based training and assessment module in radiation protection. 2. Radiation protection a holistic approach: from structured reporting to structured imaging Introduction: Structured reporting is a technique of improving the quality, shortening the turnaround time, and enhancing the interdisciplinary communication of radiologic reporting. The IT structure of such reports has been elaborated during the last years and basic templates are available for download from the homepages of several radiological societies, especially RSNA and the ESR in the near future. For the structure of the content of such type of reports, standards are currently developed and several attempts exist to bring the complexity of a radiological text into order. An important initiative is RadLex that provides us with an increasing list of radiologic terms and definitions that have already been translated from English into several other languages. When developing such report templates, it soon becomes clear that the structure of a report depends on the referral and on how the image investigation was performed. Referrals for imaging, therefore, should be structured in the same way as the reports. Depending on their structure, the structure of the investigation and the report will be driven. The aim of this project is to extend the structuring process of the radiologic workflow by starting with structuring the referral and preparing semi-standardized items for the use in automatic order entry systems. Image investigation will be structured with a strong focus on dose management and the report structure will strongly rely on the two workflow steps before. Methods: Basing on the referral guidelines of EU member states, standardized templates for use in order entry systems will be developed on a European wide scale. The same will be done for investigation techniques. Existing structured reporting templates will be improved by adding well elaborated text into the tables. All templates will be approved by an expert panel. 3. Research education and training Taking into consideration the progressive free movement of patients and health professionals across EU countries, there is a need to develop a strategy to harmonise education and training of health professionals dealing with ionising radiation to guarantee minimum acceptable levels of knowledge, skills and competences in radiation protection. Developing education and training material, combined with an audit and accreditation mechanism will result in better and safer healthcare systems.
7	The previous question seems to be biased towards risk and ethics. Then I don’t understand this question 1. you train --> research

	2. research --> educate I assume that you mean 1. what training you need for future research my answer is beside any of the main subjects to work interdisciplinary. to be able to listen and cooperate with biologists. physics. chemists. modellers. geologist etc.
8	We should not only train engineers but all future handlers of radionuclides or devices emitting radiation could- access to education course on radiation risks.
9	Mechanistic knowledge on the effect of radiation, this would strongly enhance the right decision making for dose levels etc.
10	Risks in the NORM Industries Wastes disposal Regulations Decommissioning
11	Risks in the NORM Industries Wastes disposal Regulations Decommissioning
12	Joint platforms of medical staff and radiation protection experts to better define how to train new radiation protection issues to clinics and also to patients.

Table 39: Other specialised courses respondents would find relevant to enrich or deepen their own professional expertise

	Please indicate which other specialised courses you would find relevant to enrich or deepen your own professional expertise.
	Comments: 9
1	International organisations often use courses just for advertising their work.
2	The assessment and environmental impact.
3	Interdisciplinary courses on radiation protection issues. Involve many disciplines: radiobiology, ecology, immunology, modelling, economics. ...
4	Impact on human behaviour following different training schemes . Change management.
5	Radiation protection.
6	Risk communication and risk perception.
7	Courses aimed at developing and enhancing the clinical human factors to develop good safety cultures in radiological and nuclear medicine fields in hospitals.
8	Additive radiation exposure in different lives, depending on basic health, access to high-end medical technology and sickness and disease in later years. Maybe a radiation charts, like the medical chart?
9	Decision making

4 ANNEX 1: OVERVIEW OF THE RESPONDENTS' RESPONSES TO THE OPEN QUESTIONS

Within the focus areas respondents were asked to specify other research topics for the domain or to provide further comment in free texts. This section summarizes the answers and comments to MELODI, ALLIANCE and NERIS focus areas. EURADOS focus area did not include open-ended question, and for Ethics, Risk Communication and Risk Perception and Education and Training sections, see the tables 34, 35-36 and 37-39 respectively in the main report.

MELODI

Overall, 124 people responded to the specific focus area low dose risk (MELODI). Respondents were asked to evaluate the importance and feasibility of six different topics related to three key research areas: 1) radiation-induced cancer, 2) radiation-induced non-cancer diseases, and 3) individual and general health and radiation protection issues.

In addition, respondents were asked to indicate additional issues they would like to suggest as a priority related to each of the three key research areas.

Table 5: radiation-induced cancer

Overall, there had been 23 comments on potential priorities in this field. They can be categorized as follows:

1) Answers suggesting a focus on radiation quality, LET of radiation, DDREF or risk extrapolation models (4)
2) Answers suggesting to study second cancers after radiotherapy (2)
3) Answers suggesting to focus on individual radio-sensitivity by different methods
4) Divergent comments on animal models: one states that cells and animals are not promising for low dose research, another one suggests that GM animals are good models (2)
5) Answers highlighting specific biological approaches (microenvironment and impacts at the system level, role of tissue and cancer stem cell determination, of ion-cluster-size distributions, etc.) (5)
6) Answers suggesting to focus on specific population studies (children, non-humans) (2)
7) Answers to focus on mixed exposures, to integrate molecular epidemiological studies and suggestions for new epidemiological studies (3)

Table 6: radiation-induced non cancer diseases

Overall, there had been 19 comments on potential priorities in this field. They can be categorized as follows:

1) Answers highlighting relevant endpoints to be investigated such as heart, brain, cardio-vascular diseases, central nervous system, oxidative stress, reproductive function, neurological-diseases, hematologic diseases, immune system, cataracts (8)
2) Answers stating that research in this field is difficult or not promising (4)
3) Answers mentioning that therapeutic radiation doses should be compared with low doses (2)
4) Answers highlighting specific areas in mechanistic studies (4)
5) Comment to compare x-ray and UV-induced cataracts (1)

3) *Table 9: individual and general health and radiation protection*

Overall, there had been 9 comments on potential priorities in this field. They can be categorized as follows:

1) Answers suggesting that internal contamination is an important priority (7)
2) Answer suggesting studies related to radiation-exposed patients (1)
3) Answer suggesting to focus on combined exposures (1)

ALLIANCE

Table 13: The three most important research lines from the radioecology and motivation for the three selected research lines

Respondents needed to select the research lines that they considered the MOST important to address from the radioecology SRA. The following three lines were considered as the most important lines from the radioecology over the next 20 years:

1. Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife.
2. Acquire the data necessary for parameterization of the key processes controlling the transfer of radionuclides.
3. Develop transfer and exposure models that incorporate physical, chemical and biological interactions, and enable predictions to be made spatially and temporally.

These research lines are followed by the importance of the following topics:

4. Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants).
5. Understand what causes intra- and inter-species differences in radiosensitivity (e.g. among cell types, tissues, life stages, life histories, ecological characteristics).
6. Integrate human and environmental protection frameworks.
7. Integrate uncertainty and variability from transfer modelling_ exposure assessment_ and effects characterisation into risk characterization.
8. Understand the mechanisms underlying multi-generational responses to long-term ecologically relevant exposures (e.g. maternal effects, hereditary effects, adaptive responses, genomic instability, and epigenetic processes).
9. Understand how radiation effects combine in a broader ecological context at higher levels of biological organisation (population dynamics, trophic interactions, indirect effects at the community level, and consequences for ecosystem functioning).
10. Mechanistically understand how processes link radiation induced effects in wildlife from molecular to individual levels of biological complexity.
11. Integrate the risk assessment frameworks for ionising radiation and chemicals.
12. Represent radionuclide transfer and exposure at a landscape or global environmental level with an indication of the associated uncertainty.
13. Integrate Decision Support Systems.
14. Integrate ecosystem approaches, ecosystem services and ecological economics within radioecology.
15. Provide a multi-criteria perspective in support of optimized decision-making.

Among the combinations in groups of three selected lines of research, the first three are associated with greater frequency. The first two also appear in other recurring associations, together with research line “Integrate uncertainty and variability from transfer modelling, exposure assessment, and effects characterisation into risk characterization” or “Mechanistically understand how processes link radiation induced effects in wildlife from molecular to individual levels of biological complexity”.

Respondents were also asked to justify their choices. Some comments provided multiple insights, while others focused on specific topics. The analysis of the open questions was carried out by integrating the answers and bringing out the most represented ones.

The reasons given by the respondents show that their choices were mainly guided by the awareness of the lack of adequate scientific knowledge in the selected fields: neither wildlife exposure nor transfer processes are sufficiently studied. They believe it is important to have an integrated assessment of humans and wildlife to provide unified countermeasures and protection goals. Integrating chemical and radiation exposure is needed at multiple levels, political, mechanistic, for modelling radionuclides behavior in the environment and for proper risks assessment.

The most shared research areas are those that represent important issues for risk estimation (risk arising from radiation and/or other hazards and stress factors, also in inter-comparison) and safety assessment. It is noteworthy to improve modelling for risk estimates and to build a consistent operational approach for low-dose risk in human and non-human species. The role of radioecology in the European Radiation Protection and in the perception by the public should be the identification of the key processes and pathways that lead to significant human exposure.

The purpose of the areas of interest is to provide key information for improving decision making and regulations. It is important to understand the underlying parameters governing environmental behavior for remediation purposes and preparedness, integrating this knowledge into multi criteria decision support systems.

A few considerations underscore how extrapolation methods introduce large uncertainties, difficult to quantify. Thus the environment protection needs real data (“from the lab to the real world”) of key processes at the level of the individual and at higher levels of organization; models should be controlled and backed up by experimental data. On the contrary other responders feel that parameterization and models are the only reliable way for extrapolation of field and laboratory data to the variety of species conditions found in real life.

Finally, further arguments support the relevance of understanding the differences in radiosensitivity to achieve a better understanding of DNA repair in general, of the molecular and cellular responses to radiations and of the higher levels of organization. Develop and improving human medicine is also a priority.

Table 14: Additional issues related to individual and general health and radiation protection suggested by respondents

In the opinion of some of the respondents, ALLIANCE SRA should be more focused on strategy, maintaining the attention for the experimental part and providing details on those processes which influence environmental behavior and relevant remediation activities (e.g. deposition scenarios, radionuclides and transfer mechanisms). Safety assessment for not accidental release is needed, integrating disciplines such as hydrology, meteorology and oceanography to radioecology for a best estimate of dispersal and transport of the radionuclides. Another relevant endpoint to be investigated is the quantification of the adverse effects on the biota according to the dose, supporting more integrated methods for ecological risk assessment and management goals.

Table 15: Additional comments and suggestions for the ALLIANCE SRA

Additional suggestions for the SRA include to focus on uranium mines, given their abundance and their high contribution to the environmental contamination, both in Europe and underdeveloped countries, and on ecosystems and integrated parameters to characterize the reaction of whole cenosis to radiotoxic effects. Moreover, the “One health concept", an eco- and, at the same time, anthropo-centric approach should be emphasized.

Some respondents feel the need to promote communication and encourage joint working between all parties. In this context, it is felt the need to optimize and balance the four platforms’ focuses. On the other hand, other respondents claim the essential contribution of Research, that must be funded, instead of investing mainly in integration programs and alliances.

NERIS

Table 17: Additional issues related to atmospheric dispersion modelling suggested by respondents

Respondents identified additional priorities related to atmospheric dispersion modelling:

- Development of near-range models and of common platforms for long range atmospheric dispersion and transport models
- Intermittent release and multiple release points
- Remote access to centralised modelling system

Table 19: Additional issues related to aquatic dispersion modelling suggested by respondents

A few additional priorities were suggested in this field:

- Modelling and validation of concentration profiles during post release phase for a duration of months/years in case of large costal NPP facilities
- Intermittent releases
- Technology for water purification and its influence on drinking water quality after contamination with radionuclides

Table 21: Additional issues related to improvement of existing DSS suggested by respondents

- Android based DSS with GIS facility and integrated radiological dose projections and realtime measurement data update options
- Interpretation of vast numbers of monitoring results taking into account a multiplicity of endpoints and differences in timing
- Implementing in the DSS procedures or systematic methodologies to select the most feasible countermeasure strategies for the regional or local characteristics

Table 24: Additional issues related to Improving of the decision-making processes suggested by respondents

- Realtime systems to improve decision making with experts.

Table 27: Additional issues related to use of social media and networking suggested by respondents

- Include NGOs and the public through the press
- Effective management of the news spread through social media by the Authorities
- Education and training of stakeholders affected or involved in the management of contaminated goods but without radiation protection knowledge

Table 28: Additional issues related to the improvement of preparedness for media and social media communication suggested by respondents

Social media can be used for preparedness activities and management in case of emergencies but their optimal use should be defined.

5 ANNEX 2: QUESTIONNAIRE

Introduction to the OPERRA Stakeholder survey

1.1. Purpose of the OPERRA survey

Description: Introduction
Type: Info text

[The entire text of the Introduction has been included and split into separate screens.

1. Synergies between research areas

1.1. Synergies between research areas

Description: Introduction
Type: Info text
Text: European research efforts in radiation protection need to be co-ordinated to help ensure effective and efficient use of the limited funds available. The questions below ask for your opinion of the importance and feasibility of topics that have been identified as relevant to more than one of the research areas covered by the European research platforms MELODI, NERIS, EURADOS and ALLIANCE that concern low dose risk, emergency and recovery preparedness, radiation dosimetry and radioecology respectively.

These ‘synergistic priorities’ have been developed through consultative process between the platforms as part of the OPERRA project. The results of this survey will be made available to the independent group that will write the text for the next call for research proposals run by OPERRA that is expected to be published in the last quarter of 2014

1.2. Feasibility/Importance

Description: Next steps
Type: Info text
Text: Next, you will be requested to assess the feasibility and importance of the synergistic priorities.

1.3. Feasibility/Importance

Description: Next steps
Type: 2D
Range: Feasibility: High-Low; Importance: High-Low

Question	Description
Multiple stressors and modulation of radiation effects in living organisms.	To elude mechanisms explaining how and to what extent radiation effects in organisms are modulated by the context of multiple stressors potentially present in the environment (e.g., chemicals, pathogens). Faced to the multitude of stressors in field, to develop a mode-of-action based approach for identifying stressors combinations likely to interact with ionising radiation, taking account for the biological specificities of the organism studied that vary among species.

Spatial and temporal environmental modelling and human dose assessment after a nuclear accident.	1. To develop time and space dependent models to assess the evolution of radioactivity and related dose to man dynamically from regional scale to local scale, the latter being relevant for farmers and farmer communities. 2. To develop countermeasure strategies at local level 3. To develop dose reconstruction techniques to infer doses and contamination for past days of a long lasting release and in this way improve the DSS.
Priorities for pre-accident recovery preparedness.	Develop better tools and guidance for pre-accident recovery planning to facilitate and improve accident specific remediation by defining vulnerable areas and areas of high risk around the NPP in Europe and improved radioecological models for these areas. Remediation strategy handbooks should be further developed.
Decision support based on multi-criteria decision aiding tools in the various phases of an emergency (including the post-emergency remediation phase).	Defining a framework for the application of formal decision aiding tools such as Multi-Criteria Decision Analysis (MCDA), based on economic, infrastructural, social services and dosimetric data, in the various phases of an emergency (including the post-emergency remediation phase), in order to structure the decision process and to optimise management approaches for radioactive contamination at national, regional and local levels.
Development of health surveillance procedures.	To draw lessons from Chernobyl and Fukushima situations; to develop procedures for health surveillance in a broader perspective of improving living conditions of affected populations, including sampling of population and dose reconstruction, and involvement of stakeholders; and to ensure the maximum information is obtained to refine current health risk estimates and clinical decision making.
Biological indicators of radiation exposure, effects, health risk and disease susceptibility to inform emergency management and epidemiological studies.	Biological indicators of radiation exposure and effects, particularly in relation to health play an important role in emergency management and can be integrated into epidemiological studies of risk and susceptibility. Identification of new and further validation of existing biomarkers in relation to dose and relationship to health is required. For emergency use simple and rapid methods will be of greatest benefit.

Development of monitoring strategies, processes and tools.	To improve methods and tools to enhance the efficiency of the monitoring strategy with the aim to produce a complete and consistent picture of the radiological situation during a nuclear emergency response and recovery. This includes among others the development of new and the optimization of existing resources such as mobile units, trans-border information exchange, laboratory networking, dose assessment techniques. Furthermore, the development of sound methods for extracting dose parameters for decision making from all available measurement data, i.e. environmental radiological data and exposure/contamination measurements of the affected population; and measurements by expert teams and performed by the public. Improved guidelines on monitoring strategies will be derived.
Improvement in the modelling of biokinetics and dosimetry of internal emitters	To improve the understanding of biokinetics and dosimetry of internal emitters and to validate and implement new biokinetic and dosimetric models in case of intakes of radionuclides for a better understanding of biological/health effects or to support epi-studies.
Improved organ dosimetry in epidemiological studies	For a number of tissues and organs that are important for radio-epidemiological cohorts, doses from exposures (external or internal) cannot adequately be calculated yet and computational procedures must thus be developed. This includes for example doses to the eye lens, microscale regions of the lung, or substructures of the heart. Improvements may also be achieved by advanced retrospective dosimetry methods.
Update personalized dosimetry in medical applications	Towards an integrated personalized dosimetry in medical applications that can be used as input for low dose research. This can be done by improving (1) internal microdosimetry in radiotherapy and medical imaging, (2) patient dosimetry in interventional radiology and CT examinations (3) out-of-field dosimetry for photon and particle therapy.
Investigation of the biological effectiveness of different radiation qualities and prediction of biological risks	To investigate the impact of particle track structure in terms of biological effects at the subcellular and cellular level, including radiobiological experiments and modelling; to validate the ability of track structure simulations and measurements to predict biological effects in different tissue and disease types.

The roles of genetic and epigenetic changes in heritable/transgenerational and somatic effects relevant to individual and population health.	Classically, the stochastic health effects of radiation are attributed to mutation of DNA. Further investigation is required into the potential role of defined epigenetic effects in radiation-associated somatic diseases and heritable effects. Biological models in which the relative contribution of genetic and epigenetic processes can be elucidated will be especially valuable.
Inter- and intra-species differences in radiosensitivity	To identify and understand the role of the key drivers of intra- and inter-species radiosensitivity possibly taking account for factors such as tissue, life stage, gender, age, individual. To identify biomarkers of radiosensitivity through specific molecular or cellular fingerprints, either for a specific species or for a group of species where the same mechanism(s) was(ere) evidenced.
Biomarkers of exposure and effects in living organisms	To identify the primary mechanisms of radiation induced effects at the molecular level and their propagation up to the individual level, alongside with physiological disturbances. To propose biomarkers of exposure to low doses and biomarkers of effects as early warning systems for adverse biological outcomes. The latter would be relevant to human or non-human species radioprotection, with a comparative approach aiming at identifying common and different basic processes.
Urban radioecological hydrology modelling in (post)-emergency conditions.	To understand the behaviour of radionuclides in the urban environment and in particular in drinking water systems and sewage systems and waste water treatment plants, and to develop generic transport models that can be easily customized to a particular urban area and that can predict the exceedance of contamination levels in drinking water and sewage water. The dose to the public and to most exposed workers has to be assessed.

1.4. **Question:** Are there specific areas/projects that you consider to be particularly promising to foster effective inter-disciplinary synergy?
Type: Free answer

2. Selection of focus areas

2.1. Information on focus area selection

Description: Next steps
Type: Info text
Text: This OPERRA survey aims to collect information from many areas relevant to radiation protection. Next, you are requested to choose your focus area(s) for the scientific questions. You may choose more than one focus area.

2.2. Focus area(s)

Question: Focus area(s): Please indicate in which of the focus areas you wish to respond (multiple selections possible):
Type: Multiple choice question

- Radioecology (ALLIANCE)
- Emergency and recovery preparedness (NERIS)Low dose risk (MELODI)
- Dosimetry (EURADOS)
- Ethics
- Risk communication and risk perception
- Education and Training

The sections 4-7 are answered only by those who have indicated "Low dose risk (MELODI)" in Focus area selection

3. Introduction for low dose risk

3.1. Information on question related to low dose risk (1/2)

Description: Next steps
Type: Info text
Text: Next, you will be presented with some approaches to address many of the key issues in the radiation protection.

We would value your opinion on the *importance* and *feasibility* of achieving each of these research lines, which are grouped below under three main categories: 1. Radiation-induced cancer; 2. Radiation-induced non-cancer diseases and 3. Individual and general health and radiation protection.

3.2. Information on question related to low dose risk (2/2)

Description: Next steps
Type: Info text
Text: For further reading, you may check the entire MELODI Strategic Research Agenda via the link available below.

MELODI Strategic Research agenda

4. Radiation-induced cancer

4.1. Feasibility/importance

Description: Next steps
Type: Info text
Text: Next, you will be requested to assess the *feasibility* and *importance* of research topics related to radiation-induced cancer.

4.2. Radiation induced cancer

Type: 2D question

Range: Feasibility: High-Low; Importance: High-Low

- Suitable cohorts of radiation exposed populations for molecular epidemiological studies related to cancer effects: identification, establishment and continued follow-up
- Biomarkers for radiation exposure, effects and disease: identification, development and validation.
- Development and use of suitable whole animal and human cellular models (including somatic stem cells) to study quantitative and mechanistic aspects of radiation carcinogenesis
- Impact of low dose and low dose rate radiation effects on pathways/processes contributing to carcinogenesis
- Risks associated with internal contamination with radionuclides
- Identification of the nature and number of target cells at risk for specific cancers in humans

4.3. **Question:** Are there any additional issues related to radiation-induced cancer you would like to suggest as a priority? Please specify.

Type: Open field

5. Radiation-induced non cancer diseases

5.1. Feasibility/importance

Description: Next steps

Type: Info text

Text: Next, you will be requested to assess the *feasibility* and *importance* of research topics related to radiation-induced non cancer diseases.

5.2. Radiation induced non cancer diseases

Type: 2D question

Range: Feasibility: High-Low; Importance: High-Low

- Suitable cohorts of radiation exposed populations for molecular epidemiological studies related to non-cancer effects: identification, establishment and continued follow-up.
- Biomarkers for radiation exposure, effects and disease: identification, development and validation
- Development of suitable whole animal models to study quantitative and mechanistic aspects of non-cancer diseases
- Impact of low dose and low dose rate radiation effects on pathways/processes contributing to non-cancer diseases
- Risks of non cancer diseases following internal contamination with radionuclides
- Identification of the nature and number of target cells at risk for specific non cancer diseases in humans.

5.3. **Question:** Are there any additional issues related to radiation-induced non cancer diseases you would like to suggest as a priority? Please specify.

Type: Open field

6. Individual and general health and radiation protection issues

6.1. Feasibility/importance

Description: Next steps

Type: Info text

Text: Next, you will be requested to assess the *feasibility* and *importance* of research topics related to individual and general health and radiation protection issues.

6.2. Individual and general health and radiation protection issues

Type: 2D question

Range: Feasibility: High-Low; Importance: High-Low

- Impact of inter-individual variation of radiation risks for cancer and non-cancer diseases and on dose response relationships in populations.
- Contribution to the development of radiation-associated diseases of radiation effects in target cells, the tissue environment, and their interaction at different dose levels
- Impact of low dose and low dose rate radiation effects on immune function.
- Effect of gender and/or age-at-exposure on radiation risk
- Trans-generational and heritable radiation effects
- Synergistic effects of combined exposure with environmental pollutants

6.3. Question: Are there any additional issues related to individual and general health and radiation protection issues you would like to suggest as a priority? Please specify.

Type: Open field

The sections 8-16 are answered only by those who have indicated "Radioecology (ALLIANCE)" in Focus area selection

7. Introduction to radioecology

7.1. Introduction to radioecology SRA (1/2)

Description: Next steps

Type: Info text

Text: This section addresses the Radioecology Strategic Research Agenda (SRA) developed by the ALLIANCE platform in collaboration with the EURATOM STAR and COMET consortia.

The scientific discipline of radioecology provides quantitative and integrative assessments of radionuclide impacts on man and wildlife for a wide range of exposure scenarios. The need for radioecological expertise arises: when evaluating the risks from, for example, nuclear power plants or disposal of nuclear waste; in response to nuclear accidents or possible terrorist events; and in the debate on chronic, low dose effects. As such it provides science underpinning the other radiation protection areas within the OPERRA umbrella.

7.2. Introduction to radioecology SRA (2/2)

Description: Next steps

Type: Info text

Text: The Radioecology SRA has evolved and been improved through previous consultations with an array of diverse stakeholders. The SRA responds to the question: "What topics, if critically addressed over the next 20 years, would significantly advance radioecology?"

The ALLIANCE SRA is available from the Radioecology Exchange website; the current version is an evolution taking into account comments received from the earlier consultations.

8. Information on questions related to radioecology

8.1. Information on questions related to radioecology

Description: Next steps

Type: Info text

Text: The Radioecology SRA prioritises three major scientific challenges facing radioecology, with the goal of improving research efficiency and more rapidly advancing the science.

The SRA responds to the question: "What topics, if critically addressed over the next 20 years, would significantly advance radioecology?". To address these challenges 15 key research lines are identified.

9. Previous consultation

9.1. Did you answer the questionnaire on the Radioecology SRA in 2012?

Type: Choice question

- Yes
- No

9.2. Did you attend the Paris consultation workshop in November 2012?

Type: Choice question

- Yes
- No

10. Challenge 1: To Predict Human and Wildlife Exposure in a Robust Way by Quantifying Key Processes that Influence Radionuclide Transfers and Expo

10.1. Strategic vision of Challenge 1

Type: Info text
Text: Over the next 20 years radioecology will have achieved a thorough mechanistic conceptualisation of radionuclide transfer processes within major ecosystems (terrestrial, aquatic, urban), and be able to accurately predict exposure to humans and wildlife by incorporating a deeper understanding of environmental processes.

10.2. Feasibility and importance

Description: Next steps
Type: Info text
Text: We would value your opinion on the *importance* and *feasibility* (i.e how difficult will they be to achieve over the next 20 years) of achieving each of these research lines which are grouped below by the challenge that they address.

Next please assess the feasibility and importance of the 4 research lines associated with Challenge 1.

10.3. Challenge 1

Description: Next please assess the feasibility and importance of the 4 research lines associated with Challenge 1
Type: 2D question
Range: Feasibility: High-Low; Importance: High-Low

- Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife
- Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides
- Develop transfer and exposure models that incorporate physical, chemical and biological interactions, and enable predictions to be made spatially and temporally
- Represent radionuclide transfer and exposure at a landscape or global environmental level with an indication of the associated uncertainty

11. Challenge 2: To Determine Ecological Consequences under Realistic Exposure Conditions

11.1. Strategic vision of challenge 2

Type: Info text
Text: Over the next 20 years radioecology will have gained a thorough mechanistic understanding of the processes inducing radiation effects at different levels of biological organisation, including the consequences on ecosystem integrity, and be able to accurately predict effects under realistic conditions.

11.2. Feasibility and importance

Description: Next steps
Type: Info text
Text: We would value your opinion on the *importance* and *feasibility* (i.e how difficult will they be to achieve over the next 20 years) of achieving each of these research lines which are grouped below by the challenge that they address.

Next please assess the feasibility and importance of the 5 research lines associated with Challenge 2.

11.3. Challenge 2

Type: 2D question
Range: Feasibility: High-Low; Importance: High-Low

- Mechanistically understand how processes link radiation induced effects in wildlife from molecular to individual levels of biological complexity
- Understand what causes intra- and inter-species differences in radiosensitivity (e.g. among cell types, tissues, life stages, life histories, ecological characteristics)
- Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants)
- Understand the mechanisms underlying multi-generational responses to long-term ecologically relevant exposures (e.g. maternal effects, hereditary effects, adaptive responses, genomic instability, and epigenetic processes).
- Understand how radiation effects combine in a broader ecological context at higher levels of biological organisation (population dynamics, trophic interactions, indirect effects at the community level, and consequences for ecosystem functioning)

12. Challenge 3: To Improve Human and Environmental Protection by Integrating Radioecology

12.1. Strategic vision of Challenge 3

Type: Info text
Text: Over the next 20 years radioecology will develop the scientific foundation for the holistic integration of human and environmental protection, as well as their associated management systems.

12.2. Feasibility and importance

Description: Next steps
Type: Info text
Text: We would value your opinion on the *importance* and *feasibility* (i.e how difficult will they be to achieve over the next 20 years) of achieving each of these research lines which are grouped below by the challenge that they address.

Next please assess the feasibility and importance of the 6 research lines associated with Challenge 3.

12.3. Challenge 3

Type: 2D question
Range: Feasibility: High-Low; Importance: High-Low

- Integrate uncertainty and variability from transfer modelling, exposure assessment, and effects characterisation into risk characterisation
- Integrate human and environmental protection frameworks
- Integrate the risk assessment frameworks for ionising radiation and chemicals
- Provide a multi-criteria perspective in support of optimised decision-making
- Integrate ecosystem approaches, ecosystem services and ecological economics within radioecology
- Integrate Decision Support Systems

13. Research lines

13.1. Importance of research lines

Description: Next steps
Type: Info text
Text: Next, you are presented with 15 research lines from the radioecology SRA. Please select the three you think are the MOST important to address.

13.2. Of the 15 research lines, please select the three which you think are the MOST important to address over the next 20 years

Description: Multiple choice is allowed, please choose 3
Type: Multiple choice question (max. 3)

- Identify and mathematically represent key processes that make significant contributions to the environmental transfers of radionuclides and resultant exposures of humans and wildlife
- Acquire the data necessary for parameterisation of the key processes controlling the transfer of radionuclides
- Develop transfer and exposure models that incorporate physical, chemical and biological interactions, and enable predictions to be made spatially and temporally
- Represent radionuclide transfer and exposure at a landscape or global environmental level with an indication of the associated uncertainty
- Mechanistically understand how processes link radiation induced effects in wildlife from molecular to individual levels of biological complexity
- Understand what causes intra- and inter-species differences in radiosensitivity (e.g. among cell types, tissues, life stages, life histories, ecological characteristics)
- Understand the interactions between ionising radiation effects and other co-stressors (i.e. multiple contaminants)
- Understand the mechanisms underlying multi-generational responses to long-term ecologically relevant exposures (e.g. maternal effects, hereditary effects, adaptive responses, genomic instability, and epigenetic processes).
- Understand how radiation effects combine in a broader ecological context at higher levels of biological organisation (population dynamics, trophic interactions, indirect effects at the community level, and consequences for ecosystem functioning)
- Integrate uncertainty and variability from transfer modelling, exposure assessment, and effects characterisation into risk characterization
- Integrate human and environmental protection frameworks
- Integrate the risk assessment frameworks for ionising radiation and chemicals
- Provide a multi-criteria perspective in support of optimised decision-making

- Integrate ecosystem approaches, ecosystem services and ecological economics within radioecology
- Integrate Decision Support Systems

13.3. Please explain why you selected your three MOST important research lines

Type: Open field

14. Priority of situation

14.1. Priority of situation

Description: Next steps
Type: Info text
Text: Next, you are requested to indicate for your three MOST important research lines, which situation(s) should receive priority when they are being addresses.

14.2. Priority of situation

Type: Multiple choice question
The responder will be presented with the 0-3 research lines chosen earlier, and requested to indicate which situation(s) should receive priority for each chosen research line

- Routine releases from nuclear facilities
- Accident/Post accident
- NORM/TeNORM
- Other

15. Missing research lines and additional comments

15.1. Are there important research lines which you consider are missing from the SRA? Please explain why you think they should be included.

Type: Open field

15.2. We welcome any additional comments and suggestions

Type: Open field

The sections 17-24 are answered only by those who have indicated "Emergency and recovery preparedness (NERIS)" in Focus area selection

16. Introduction to emergency and recovery preparedness

The **European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery (NERIS Platform)** was launched in June 15, 2010. Research and development in the field of emergency management and recovery at the European level calls for co-operation between authorities, emergency centres, research organisations and the academic community in different countries, as well as interactions with key concerned stakeholders. The NERIS Strategic Research Agenda (SRA) contains broader areas where further research and development are needed.

Seven Key Topics are identified and grouped in three research areas as follows:

1. New challenges in atmospheric & aquatic modelling – Needs for improvement.
2. New challenges for better dose assessments and decision support based on improved knowledge: source term, scenarios, etc.
3. New challenges in stakeholder involvement and local preparedness and communication strategies.

For further reading, you may check the entire NERIS Strategic Research Agenda via the link available below.

NERIS SRA

17. Research Area 1 - Key Topic 1

17.1. Research area 1: New challenges in atmospheric & aquatic modelling – Needs for improvement

Description: Introduction
Type: Info text
Text: Key Topic 1: Atmospheric dispersion modelling - Needs for improvement aims at making more reliable and precise forecasts on atmospheric dispersion of radioactive materials in different environments. This will extend the capabilities of Decision Support Systems and will provide decision makers and other actors with a more reliable picture of the situation.

17.2. Feasibility and importance

Description: Next steps
Type: Info text
Text: Next, you are requested to indicate the importance/feasibility of the topics related to Atmospheric dispersion modelling:

17.3. Research area 1, key topic 1

Type: 2D question
Range: Feasibility: High-Low; Importance: High-Low

- Modelling approaches for complex settings (e.g. urban, confined spaces).
- Data assimilation (e.g. dose rates and concentrations) and inverse modelling
- Dispersion models for non-conventional emissions (e.g. explosions, two-phase, aerosol sprays, fires, etc.) of particular substances (e.g. aerosol, phase-changing, multi-sized particles, etc.)
- Fine tuning modeling parameters & algorithms (to treat specific phenomena such as wet deposition by snow)
- Optimised use of new meteorological instruments (esp. mobile measurement units)
- Simulation of (very) long-duration releases (>1 month) to air

17.4. **Question:** Are there any additional issues related to atmospheric dispersion modelling issues you would like to suggest as a priority? Please specify.

Type: Open field

18. Research Area 1 - Key Topic 2:

18.1. Research area 1: New challenge*s* in atmospheric & aquatic modelling – Needs for improvement

Description: Introduction
Type: Info text
Text: Key Topic 2: Aquatic dispersion modelling aims at improving forecasts on aquatic dispersion of radioactive materials in different environments (urban hydrology systems and coastal waters). This will extend the capabilities of Decision Support Systems and will provide decision makers and other actors with a more reliable picture of the situation by allowing to assess:

- The vulnerability of urban hydrology systems to nuclear emergencies regarding the freshwater supply system and waste- water contamination from deposited radionuclides.
- The dispersion of radioactivity in coastal waters and radioactivity levels in fish and seafood.

18.2. Feasibility and importance

Description: Next steps
Type: Info text
Text: Next, you are requested to indicate the importance/feasibility of the topics related to Aquatic dispersion modelling:

18.3. Research area 1, key topic 2

Type: 2D question
Range: Feasibility: High-Low; Importance: High-Low

- Models for urban hydrology (contamination of urban fresh water supply & waste water from urban decontamination)
- 3D models for coastal areas (including long duration releases)
- Coupling with weather forecast models for running in the automatic mode of a Decision Support Systems and with sediment transport models
- Runoff (land to sea) models
- Development of finite volume models (e.g. for prolonged emergency phase modelling)

18.4. **Question:** Are there any additional issues related to aquatic dispersion modelling issues you would like to suggest as a priority? Please specify.

Type: Open field

19. Research Area 2 - Key Topic 3:

19.1. Research area 2: New challenge*s* for better dose assessments and decision support based on improved knowledge: source term, scenarios, etc

Description: Introduction
Type: Info text
Text: Key topic 3 Improvement of existing Decision Support Systems aims at obtaining a better analysis of the radiological situation (source-term, scenarios, etc.), and at supporting the decision-making processes at all (emergency and recovery) phases after an event. Expected results are:

- A better source-term input within dispersion models
- An improvement of radio-ecological modelling
- A better customization of Decision Support Systems according to local information

- A better response to malevolent acts
- A better analysis and response in the different exposure situations

19.2. Feasibility and importance

Description: Next steps
Type: Info text
Text: Next, you are requested to indicate the importance/feasibility of the topics related to Improvement of existing Decision Support Systems:

19.3. Research area 2, key topic 3

Type: 2D question
Range: Feasibility: High-Low; Importance: High-Low

- Better quantification of source terms (according specific type of accidents and physico-chemistry of released substances)
- Customising of the existing environmental models into the regional circumstances in Europe
- Measurements of Chernobyl and, if possible, Fukushima contaminants on different surfaces
- Development of local radio-ecological models
- Improvement of existing DSS for radiological emergencies (e.g. explosions in large buildings, underground events, uncertain source-term information, hidden sources, etc.)
- Tackle multiple stressors (e.g. CBRNE) in the assessment of countermeasure strategies
- Tailor the output of DSS's to the users' needs
- Development of rapid analytical tools with mobile and automated equipments

19.4. **Question:** Are there any additional issues related to improving existing Decision Support Systems you would like to suggest as a priority? Please specify.

Type: Open field

20. Research Area 2 - Key Topic 4

20.1. Research area 2: New challenge*s* for better dose assessments and decision support based on improved knowledge: source term, scenarios, etc

Description: Introduction
Type: Info text
Text: Key topic 4 Data mining, information gathering and providing information to stakeholders and mass media aims at fostering the information exchange between all interested stakeholders, and at providing means for a more transparent decision-making process. Expected results are:

- To develop an information exchange platform for all relevant organisations in Europe
- To allow decision-makers to learn lessons from historic events

20.2. Feasibility and importance

Description: Next steps
Type: Info text
Text: Next, you are requested to indicate the importance/feasibility of the topics related to Data mining, information gathering and providing information to stakeholders and mass media

20.3. Research area 2, key topic 4

Type: 2D question
Range: Feasibility: High-Low; Importance: High-Low

- Establishment of a Europe-wide analytical platform for operational data and information exchange
- Development of a knowledge database ('lessons to be learned from historic events')

- Understanding of what could make the information trustworthy and more effective (e.g. development and usage of social media in emergency response; communication-cooperation with the public)

21. Research Area 2 - Key Topic 5

21.1. Research area 2: New challenge*s* for better dose assessments and decision support based on improved knowledge: source term, scenarios, etc

Description: Introduction
Type: Info text
Text: Key topic 5 Improving of the decision-making processes aims at improving decision processes. Expected results are:

- Better structured decision processes at national, regional and local levels involving the different categories of stakeholders (public authorities, professionals, inhabitants)
- A more accurate information to the emergency and recovery stakeholders
- A more efficient use of existing Decision Support Systems and tools
- A better allocation of resources and improvement of the efficiency of protective strategies during emergency and recovery phases

21.2. Feasibility and importance

Description: Next steps
Type: Info text
Text: Next, you are requested to indicate the importance/feasibility of the topics related to Improving of the decision-making processes

21.3. Research area 2, key topic 5

Type: 2D question
Range: Feasibility: High-Low; Importance: High-Low

- Assessment of and communication on uncertainties
- Coupling of Decision Support Systems with Command and Control systems
- Improvement of decision-making processes through the development of guidances and multi-criteria analysis decision-aiding tools, taking into account the feedback from stakeholder processes (e.g. from Fukushima)
- Development of serious gaming (for stakeholder education and training)
- Revision of European handbooks considering malevolent acts
- Development of tools for the usage at the local level, which are compatible with those used at the national ones (e.g. integrated GIS systems)
- Development of sustainable strategy at local, national and European levels based on the analysis of countermeasures for relevant accident scenarios
- Development of health surveillance procedures
- Development of monitoring strategies, processes and tools (thanks to an optimised used of resources such as mobile units, trans-border information exchange and monitoring crowdsourcing)

21.4. **Question:** Are there any additional issues related to improving decision-making processes you would like to suggest as a priority? Please specify.

Type: Open field

22. Research Area 3 - Key Topic 6

22.1. Research area 3: New challenges in stakeholder involvement, local preparedness and communication strategies

Description: Introduction
Type: Info text
Text: Key topic 6 Stakeholder management and dialogue aims at improving the acceptability and social robustness of emergency response, ensuring that stakeholders are involved in decisions that impact on their lives
Expected results are:

- To maintain the inclusion of social aspects of emergency response and stakeholder engagement
- A greater recognition of the importance of stakeholder and public engagement
- To improve understanding of the factors and criteria for successful stakeholder engagement

22.2. Feasibility and importance

Description: Next steps
Type: Info text
Text: Next, you are requested to indicate the importance/feasibility of the topics related to Stakeholder engagement and dialogue

22.3. Research area 3, key topic 6

Type: 2D question
Range: Feasibility: High-Low; Importance: High-Low

- Defining stakeholders and framing problems (identifying the roles, responsibilities and co-operation among national/regional/local stakeholders)
- Stakeholder engagement database (lessons learned from past experiences)
- Development of guidance on information and participation of affected population
- Guidelines and strategies on the contaminated goods management

22.4. **Question:** Are there any additional issues related to improving stakeholder engagement and dialogue you would like to suggest as a priority? Please specify.

Type: Open field

23. Research Area 3 - Key Topic 7

23.1. Research area 3: New challenges in stakeholder involvement, local preparedness and communication strategies

Description: Introduction
Type: Info text
Text: Key topic 7 Use of social media and networking aims at better understanding the ways in which social media and other media are used in the flow of information and communication. Expected results are to improve preparedness for media and social media communication.

23.2. Feasibility and importance

Description: Next steps
Type: Info text
Text: Next, you are requested to indicate the importance/feasibility of the topics related to Use of social media and networking

23.3. Research area 3, key topic 7

Type: 2D question

Range: Feasibility: High-Low; Importance: High-Low

- Analysis of public behaviour response (i.e. understand how the public reacts and which information related to people's behaviours can be used by local-national tools to improve response)
- Assessment of the mechanisms by which the public gains information in media and social media
- Assessment of important factors for social trust in emergency situations

23.4. Question: Are there any additional issues related to preparedness for media and social media communication you would like to suggest as a priority? Please specify.

Type: Open field

The sections 27-32 are answered only by those who have indicated "Dosimetry (Eurados)" in Focus area selection

24. Introduction to Dosimetry

The European Radiation Dosimetry Group (EURADOS) consists of a self-sustainable network whose aim is to promote research and development and European cooperation in the field of dosimetry of ionizing radiation.

The EURADOS SRA is expected to contribute to identify future research needs in radiation dosimetry. This SRA is based on input from EURADOS Working Group members and takes into account the comments from consultations within Eurados members.

The current version is available on the EURADOS web site: EURADOS SRA. The present document formulates five visions in dosimetry and defines – for each vision – two to five challenges, leading to a total of 18 challenges.

25. Vision 1: Towards updated fundamental dose concepts and quantities

25.1. Feasibility and importance of Vision 1: Towards updated fundamental dose concepts and quantities

Description: Next steps

Type: Info text

Text: Next, you are requested to assess the importance and feasibility of challenges related to Eurados SRA Vision 1: Towards updated fundamental dose concepts and quantities.

25.2. Vision 1: Towards updated fundamental dose concepts and quantities

Type: 2D question

Range: Feasibility: High-Low; Importance: High-Low

- To improve understanding of spatial correlations of radiation interaction events
- To quantify correlations between track structure and radiation damage

- To improve understanding of dosimetry and biokinetics of internal emitters
- To Update Operational Quantities for External Exposure

26. Vision 2: Towards improved radiation risk estimates deduced from epidemiological cohorts

26.1. Feasibility and importance of Vision 2: Towards improved radiation risk estimates deduced from epidemiological cohorts

Description: Next steps
Type: Info text
Text: Next, you are requested to assess the importance and feasibility of challenges related to Eurados SRA Vision 2: Towards improved radiation risk estimates deduced from epidemiological cohorts

26.2. Vision 2: Towards improved radiation risk estimates deduced from epidemiological cohorts

Type: 2D question
Range: Feasibility: High-Low; Importance: High-Low

- To explore exposure pathways not yet considered or validated
- To improve retrospective dosimetry for exposure pathways already considered

27. Vision 3: Towards an efficient dose assessment in case of radiological emergencies

27.1. Feasibility and importance of Vision 3: Towards an efficient dose assessment in case of radiological emergencies

Description: Next steps
Type: Info text
Text: Next, you are requested to assess the importance and feasibility of challenges related to Eurados SRA Vision 3: Towards an efficient dose assessment in case of radiological emergencies

27.2. Vision 3: Towards an efficient dose assessment in case of radiological emergencies

Type: 2D question
Range: Feasibility: High-Low; Importance: High-Low

- To identify and characterize new markers of exposure
- To develop strategies and methods to increase measurement capacity
- To quantify doses after accidental internal contamination
-

28. Vision 4: Towards an integrated personalized dosimetry in medical applications

28.1. Feasibility and importance of Vision 4: Towards an integrated personalized dosimetry in medical applications

Description: Next steps
Type: Info text
Text: Next, you are requested to assess the importance and feasibility of challenges related to Eurados SRA Vision 4: Towards an integrated personalized dosimetry in medical applications

28.2. Vision 4: Towards an integrated personalized dosimetry in medical applications

Type: 2D question
Range: Feasibility: High-Low; Importance: High-Low

- To improve out-of-field dosimetry for photon and particle therapy
- To improve dosimetry in modern external beam radiotherapy
- To improve internal microdosimetry in radiotherapy and medical imaging
- To optimize dose estimations in interventional radiology
- To establish reliable patient dosimetry in CT examinations

29. Vision 5: Towards an improved radiation protection of workers and the public

29.1. Feasibility and importance of Vision 5: Towards an improved radiation protection of workers and the public

Description: Next steps
Type: Info text
Text: Next, you are requested to assess the importance and feasibility of challenges related to Eurados SRA Vision 5: Towards an improved radiation protection of workers and the public

29.2. Vision 5: Towards an improved radiation protection of workers and the public

Type: 2D question
Range: Feasibility: High-Low; Importance: High-Low

- To improve, validate and implement new biokinetic models
- To develop calibration procedures for partial body counters
- To develop accurate and on-line personal dosimetry for workers
- To improve neutron dosimetry techniques
- To include nuclide-specific information in environmental monitoring

The sections 33-35 are answered only by those who have indicated “Ethics” in Focus area selection

30. Radiation protection concerns us all – questions on ethics

30.1. Introduction to ethics

Description: Next steps
Type: Info text
Text: Given the nature of the radiological risk, the question of whether the use of nuclear technology is justified in a specific context has to take into account many uncertainties and unknowns. On the one hand, there are the scientific uncertainties that complicate the quantification of low dose effects. On the other hand, there is the fact that safety and security measures can never exclude human error and malevolence or fully anticipate potentially dangerous events and their development over time.

Whether in the context of medical applications, industrial uses or energy production, the justification of the use of nuclear technology can thus only partly rely on scientific evidence and needs to take into account value judgements of all concerned, either due to a mandatory responsibility or because of being a potentially affected person (e.g. patients, citizens, scientists, workers, doctors, engineers, managers, NGO representatives and policy makers). In this sense, the ethics of justification and radiation protection relate to taking value judgements into account in a responsible way, respecting human dignity, capacities and autonomy and the value of the environment, and acting accordingly.

Together with the ethical aspects dealing with adverse or unintended effects (e.g. severe normal tissue reactions to radiotherapy and post-accident measures), these judgements make up the ethical dimension of radiation protection in an occupational context and in society at large. Next, you are presented with questions related to these aspects.

31. General questions on ethics

31.1. **Question:** Do you agree with the understanding of ethics in relation to radiation protection as presented here?

Type: Choice question

- Yes completely
- Yes partially
- No

31.2. **Question:** Should ethical aspects related to the use of nuclear technology be included in future research priorities?

Type: Choice question

- Yes
- No
- I don't have an opinion

32. Thematic areas related to ethics

32.1. **Question:** Next, you are requested to indicate which thematic areas related to ethics you would find relevant to be considered in future research.

Type: Choice question, scale

• The development of ethical case studies in medical context • The development of ethical case studies in nuclear energy context • The development of ethical case studies in industrial and NORM context • Theories of ethics in relation to practical considerations on the use of nuclear technology • Ethical issues in relation to research methodologies and interpretation of results • Ethical issues specific to radiobiology research • The relation between ethics and mandatory skills and competences of scientists, managers, communicators, qualified experts, … • The relation between ethics and regulation, and the implications for the radiation protection system • The issue of dose records and privacy in occupational context • The issue of genetic susceptibility as a factor in radiation protection regulation	*1. Irrelevant* *2. Rather irrelevant* *3. Neither irrelevant, nor relevant* *4. Rather relevant* *5. Very relevant* *9. Don't know/no answer*

- The issue of gender equity in employment in work areas that involve a radiation risk
- The relation between ethics and the ALARA approach.
- The relation between ethics and nuclear safety culture
- The relation between ethics and nuclear security
- The relation between ethics and risk communication

32.2. **Question:** Are there any other thematic areas related to ethics you would find relevant to be considered in future research? Please specify.

Type: Open field

32.3. **Question:** Taking into account various possible understandings of ethics in relation to the use of nuclear technology and the various thematic areas that may be considered relevant in this sense, would a separate Strategic Research Agenda (SRA) related to ethics be useful?

Type: Choice question

- Yes
- No
- I don't have an opinion

32.4. **Question:** In relation to the previous question, if you would consider a separate SRA related to ethics be useful, would you recommend to consider all application contexts (medical, energy, industrial) in one SRA or to develop an SRA for each application context separately?

Type: Choice question

- SRA on ethics considering all application contexts (medical, energy, NORM/industrial)
- Separate SRAs on ethics for distinct application contexts (medical, energy, NORM/industrial)
- I don't have an opinion

The section 36 is answered only by those who have indicated "Risk communication and risk perception" in Focus area selection.

33. Risk communication and risk perception

33.1. Introduction

Despite 50 years of extensive research, risk perception and risk communication are relatively new disciplines in social sciences and are barely applied in the field of low doses of ionizing radiation. Moreover, it was already indicated in the OPERRA project that a collaboration between social, human and natural sciences in the field should be encouraged. In order to identify a need for and possible research topics from this trans-disciplinary field, we would appreciate your opinion about the following questions and statements.

33.2. **Question:** In the next questions, we would like to gauge your opinion on the quality of communication to the public about risk associated with low doses of ionising radiation. In general, are you satisfied with the way the following actors communicate and provide information about low doses of ionising radiation?

C1	Regulators	*1. Very unsatisfied* *2. Rather unsatisfied* *3. Neither satisfied, nor unsatisfied* *4. Rather satisfied* *5. Very satisfied* *9. Don't know/no answer*
C2	Medical personnel in hospitals	
C3	Family doctors or dentists	
C4	Mass-media	
C5	Scientists from universities	
C6	Research centres	
C7	The nuclear industry	
C8	State Agencies	
C9	NGO's	

33.3. Question: How much do you agree with the following statements related to communication and risk perception of low doses of ionising radiation?

C10	Research on risk communication and risk perception should provide more information related to good practices in interaction with a society	*1. Completely disagree* *2. Disagree* *3. Neither agree, nor disagree* *4. Agree* *5. Completely agree* *9. Don't know / NA*
C11	If I want to, I can get enough scientific results from the field of risk communication to communicate successfully with stakeholders about low doses.	
C12	We need to support more research in the field of risk communication and risk perception of low doses.	
C13	Scientific uncertainties related to low doses are one of the main challenges for efficient risk communication.	
C14	To involve new mass media in our communication about ionizing radiation we need more social science research to study the influence of this type of communication on understanding of complex concepts and perception of radiological risks by lay people.	

33.4. Question: Would further research into risk communication be beneficial to radiation protection?

Type: Choice question

- Yes
- No
- Don't know / No anwer

33.5. Question: Are there issues and topics related to risk perception and risk communication that would require new or more research in the field of low doses? Please specify.
Type: Open field

33.6. Question: Would it be useful to develop a strategic research agenda for risk communication in radiation protection?
Type: Choice question

- Yes
- No
- Don't know / No answer

33.7. Question: Do you know research institutes that perform research related to risk perception and risk communication in the field of low doses of radiation? If yes, please indicate these institutions and, if possible, specific departments and/or researchers.

Type: Open field

The section 37 is answered only by those who have indicated "Education and Training" in Focus area selection

34. Education and Training

34.1. Information

Type: Info text
Text: Nowadays, the offer of academic and professional education and training programmes devoted to the science and engineering of nuclear technology, radiobiology, radiation protection and safety culture in European context is wide and well established. While European education and training policy is concerned with streamlining, integration and cooperation in the interest of quality assurance and effective use of financial and human resources, there remains the need for high-level specialised courses adapted to the specific needs of researchers, engineers, managers and mandatories responsible for radiation protection and safety culture.

The following questions aim to sense your opinion on education and training matters in general and with respect to your own professional context.

34.2. Question: Do you consider yourself to be aware of the radiation protection education and training opportunities available in Europe?
Type: Line question. Level of awareness: Not aware – Very aware

34.3. Question: Are your education and training needs met by the existing courses/materials available in Europe?
Type: Choice question

- Yes
- No
- Don't know / No answer

34.4. Question: Do you have suggestions for additional training courses/materials that would benefit radiation protection? Please specify below.
Type: Free answer

34.5. Question: Next, you are requested to indicate, which education and training matters you would find relevant to be considered in future research.
Type: Choice question, scale

• Harmonisation of qualification standards • The development of ethical case studies for education and training purposes • The integration of courses on ethical and political aspects of technology assessment in standard academic programmes for scientists and engineers • The integration of courses on risk perception and risk communication of ionizing radiation in standard academic programmes for scientists and engineers.	*1. Irrelevant* *2. Rather irrelevant* *3. Neither irrelevant, nor relevant* *4. Rather relevant* *5. Very relevant* *9. Don't know/no answer*

34.6. Question: Please specify which other education and training matters you would find relevant to be considered in future research.
Type: Open field

34.7. Question: Please indicate which specialised courses you would find relevant to enrich or deepen your own professional expertise.
Type: Choice question, scale

• Harmonisation of qualification standards • The role and working of international institutions concerned with radiation protection recommendations and regulation (ICRP, IAEA, UNSCEAR, ...) • Ethical case studies • Ethics and radiological risk governance • Research ethics • Risk communication and risk perception	*1. Irrelevant* *2. Rather irrelevant* *3. Neither irrelevant, nor relevant* *4. Rather relevant* *5. Very relevant* *9. Don't know/no answer*

34.8. Question: Please indicate which other specialised courses you would find relevant to enrich or deepen your own professional expertise
Type: open field

At the end, we can again add some general sections to be answered by all.

35. Background information

35.1. Personal or institutional

Description: Please indicate whether you are responding in a personal or institutional capacity:
Type: Choice question

- My answers represent my personal opinion.
- My answers represent institutional opinion. If you choose this answer, please also write the name of the institution in the field below.
    - Open field

35.2. Type of institution

Description: At what kind of institution do you mainly work (multiple selections possible)?
Type: Multiple choice question

- Scientific institution (eg. university, institute…)
- Regulatory body
- Controlling authorities
- Users of ionizing radiation (e.g. hospital, operator of nuclear installation…)
- Industry
- Consultancy
- International organisation
- NGO
- I don't work in any institution currently (eg. retired). Additional explanations may be indicated in the open field below.
    - Open field
- Other. If you choose this, please describe the type of institution you are working into the open field below:
    - Open field

35.3. Nature of involvement

Description: What is your main involvement in the field of radiation protection?
Type: Choice question

- I am mainly involved in research
- I am mainly involved in controlling and advisory activities
- I perform a regulators work
- I work in the nuclear industry
- I am a radiation worker in the health care sector
- I am a member of a public with an interest in the radiation protection field
- None above. If you choose this, please describe the nature of your involvement in the open field below:.
    - Open field

35.4. Geographical background

Description: Please indicate the geographic area where you work:
Type: Choice question

- EU member state

- Other European country
- Other. Please specify in the open field below:
    - Open field

35.5. Experience

Description: For how long you have been interested in / worked in radiation protection (including education)?
Type: Choice question

- Less than 5 years
- 6-15 years
- 16-25 years
- 26-35 years
- More than 35 years

35.6. Level of information on scientific basis of radiation protection

Description: How well are you informed on the priorities of radiation protection research in the European strategic research agendas?
Type: Choice question

- Very well informed
- Fairly well informed
- Not so well informed
- Not at all informed

35.7. Organisation's current involvement

Description: Please indicate you organisation's current involvement within existing platforms (multiple selections possible):
Type: Multiple choice question

- NERIS
- EURADOS
- ALLIANCE
- MELODI
- None of the platforms above
- Other relevant EC project/activity. Please specify:

36. Contact details and further communication

36.1. Your contact details

Description: Please provide your contact details so that we can let you know when the results of the survey are available. You can also choose to answer anonymously and skip this screen.

- First name
- Last name
- Organisation
- Country
- E-mail address

36.2. In case you added your e-mail address to the previous screen, please let us know whether you would like to receive further information about the OPERRA project?

- Yes, please
- No, thank you

36.3. Additional comments

Question: Is there anything else you would like to ask or comment?
Type: Open field

6 ANNEX 3: PRACTICAL INSTRUCTIONS FOR RESPONDERS

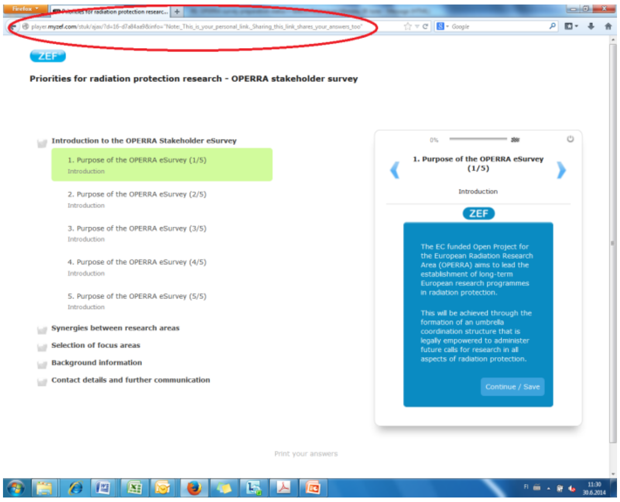
OPERRA eSurvey:
Practical instructions to the responders

Here you can find some practical instructions regarding:

- Interrupting and returning back
- Question types
- Selection of focus areas
- Completion of the eSurvey

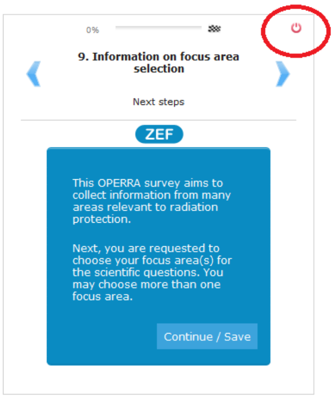
Interrupting and returning back:

When you open the link to the OPERRA e-survey, you are automatically directed to a personal page for your answers (see the address bar below):

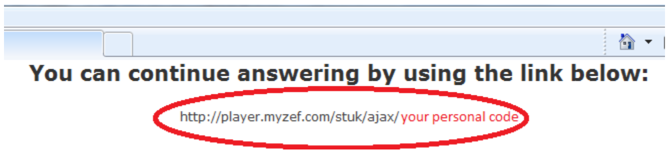


In case you want to interrupt the responding and continue later, you can simply copy this address and save it to your archives. When you wish to continue responding, just paste your personal address to the browser's address bar again and you can continue from where you left.

Alternatively, you can click on the "power off" –button on the upper right side. Then, the system gives you your personal link which you again have to copy and save in your archives in order to continue from where you left.



Copy this address to a place where you can find it:



In case you want to exit without saving your answers, you can just close the browser.

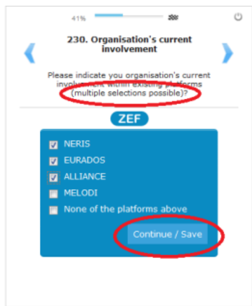
Question types:

Choice question:

Allows you to make one choice. After selecting, you are automatically moved to the next question. If you want to go back/forward, you can use the blue arrows next to the question:

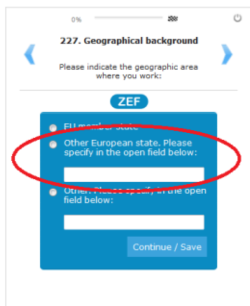
Multiple choices:

Allows you to choose more than one choice (in some cases the maximum is defined). After making your selections, press Continue/Save:

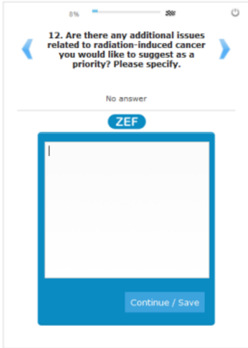


Choice + additional text:

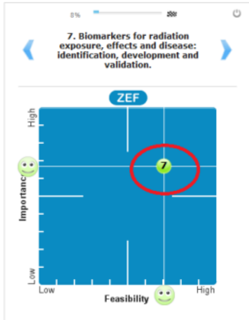
In both one choice and multiple choices questions, it is sometimes requested to provide additional information next to the choice:



Free answer: You can write text freely:

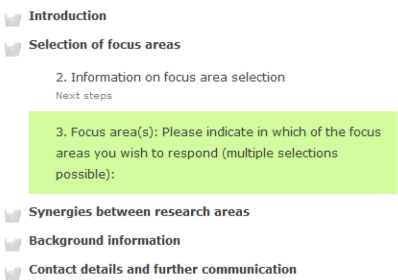


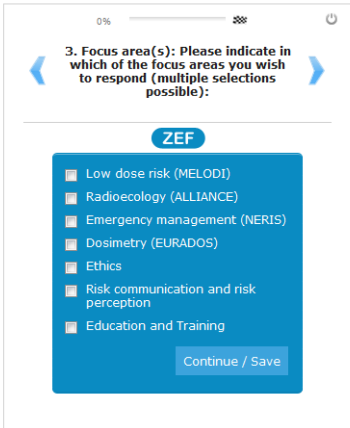
2D-assessment: Make your assessment by placing the mouse on the appropriate place in the 2D-field:



Selection of focus areas:

The OPERRA eSurvey consists of selectable focus areas as well as some common sections to all responders. You are requested to select the focus area(s) you want to respond to, and then the system automatically leads you to the questions related to selected areas.





In case you want to change your selection of the focus areas during the responding, you can return to this screen from the menu bar on the left side of the screen, by clicking on the heading: Selection of focus areas and then modifying your selection.

Completion of the eSurvey:

At the end of the eSurvey, you will get information on how many questions you responded. You can either press “Done” and submit the answers, or “Modify your answers” which allows you to go back and change your answers.